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ACOUSTIC AND AERODYNAMIC PERFORMANCE OF A 1.5-PRESSURE-RATIO, 1.83-METER (6-FT) DIAMETER FAN STAGE FOR TURBOFAN ENGINES (QF-2)

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16. Abstract

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ACOUSTIC AND AERODYNAMIC PERFORMANCE OF A 1.5-PRESSURE-RATIO, 1.83-METER (6-FT) DIAMETER FAN STAGE FOR TURBOFAN ENGINES (QF-2)

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SUMMARY

A 1.5-stage-pressure-ratio, 1.83-meter (6-ft) rotor-tip-diameter experimental fan stage designated QF-2, was tested for aerodynamic and acoustic performance at the NASA Lewis quiet fan facility. The fan was externally driven by an electric motor. Design features for low-noise generation included the elimination of inlet guide vanes, long axial spacing between the rotor and stator blade rows, and the selection of blade-vane numbers to achieve duct-mode cutoff. Fan QF-2 was tested with three nozzle areas. The fan QF-2 results were compared with those for another full-scale fan having essentially the same aerodynamic design except for nozzle geometry and direction of rotation. Fan QF-2 used a variable-area nozzle, which was somewhat longer and of slightly different exit geometry than the fixed-area nozzles used on the other two fans. Also, the fan QF-2 aerodynamic results were compared with those obtained for a 50.8-centimeter (20-in.) rotor-tip-diameter model of the opposite-rotating fan QF-2 design.

A comparison of the aerodynamic results for the full-scale and model fans showed fan QF-2 with the variable-area nozzle to be operating along the same speed line but at a lower mass flow than corresponding nozzle area results for the other fan with the fixed-area nozzle.

Multiple-pure-tone generation for fan QF-2 became more significant at more open nozzle areas.

Acoustic probes were radially traversed ahead of the rotor and behind the stator of fan QF-2. A decrease in noise level with insertion distance from the outer wall was observed at both locations at 60 percent of fan design speed.

INTRODUCTION

The QF-2 fan is one of a series of full-scale (1.83-m rotor tip diam) externally driven experimental fans tested at the NASA-Lewis outdoor fan facility. (Fig. 1 shows fan QF-2 installed in this facility.) These fans were tested as part of an overall technology program in support of the design of prototype low-noise turbofan engines. This report presents the aerodynamic and acoustic results for the QF-2 fan tests.

Fan QF-2 was designed for low-noise generation and with features suitable for a conventional takeoff and landing (CTOL) aircraft. The design stage pressure ratio is 1.5, and the stage is designed for a thrust of 105 960 newtons (23 820 lbf). Design features for low-noise generation include the elimination of inlet guide vanes, large axial spacing between the rotor and stator blade rows (3.6 rotor chords), selection of blade-vane numbers to achieve duct-mode cutoff at the blade-passage-tone fundamental, and low design rotor tip speed (337.4 m/sec).

Another fan stage (QF-1), essentially identical in design to fan QF-2 except for direction of rotation had been tested previously at the Lewis fan facility. Results for fan QF-1 have appeared several times in the literature. The first fan QF-1 tests were performed with the fan installed on a shorter shaft (i.e., closer to the drive-motor building) than the installation used for fan QF-2 (fig. 1) and subsequent tests at the fan facility. References 1 and 2 present results of these fan QF-1 tests.

The possibility of facility-induced inflow distortions is addressed in reference 3, which compares results for fans QF-1 and QF-2. This reference concludes that there was considerable inflow distortion, hence, increased noise generation, associated with the fan QF-1 installation. Thus, the fan QF-2 acoustic results presented in this report are considered more representative than those for the essentially identical fan QF-1 given in reference 2.

The one-third-octave sound-pressure-level analyzer used for the fan QF-1 analysis was replaced by a more accurate system for the fan QF-2 data reduction and subsequent fans tested at the Lewis fan facility. Hence, in addition to facility inflow improvements due to the extended shaft, the fan QF-2 data reduction is considered more accurate.

The previously published information on fan QF-1 (i.e., refs. 1 and 2) provided minimal information on the fan stage design, whereas a comprehensive discussion of the fan QF-2 (also QF-1) design is presented in an appendix of this report.

More recently, the opposite-rotating version of fan QF-2 was also tested in the installation shown in figure 1, with the stage QF-1 now designated as QF-1B because of instrumentation changes. Fan QF-1B was only run with the design-area nozzle for far-field noise data. Selected QF-1B results are presented in this report for far-field noise data. Selected QF-1B results are presented in this report for comparison with those for fan QF-2. Since the test installation is identical for these two fans, the only differences

between these stages is the direction of fan rotation and effects due to the different exhaust nozzles used on the two stages.

A 50.8-centimeter (20-in.) rotor-tip-diameter model of fan QF-1 was tested in a much more extensively instrumented indoor facility at Lewis (ref. 4). Selected aerodynamic results from these tests are included for comparison in this report.

Aerodynamic results are presented in terms of corrected mass flow, stage pressure ratio, and stage adiabatic efficiency. The QF-2 fan far-field acoustic results are presented for sound pressure level at various azimuths, sound power levels, and perceived noise levels, based on one-third-octave data. Selected narrow-band sound-pressure-level spectra are also presented. Acoustic probes were radially traversed in the inlet duct ahead of the rotor and in the exhaust duct downstream of the stator. Selected one-third-octave and narrow-band results of the acoustic probe data are presented in this report.

FAN QF-2 CHARACTERISTICS

An in-depth presentation of the QF-2 fan design is given in appendix A of this report. Reference 4, which presents the model fan aerodynamic results, includes detailed design and measured blade-element performance for this stage.

A summary of major design characteristics of fan QF-2 is presented in table I. Figures 2 and 3 are photographs of the QF-2 fan rotor and stator blades. Figure 2 shows a closeup of a section of the rotor and a view of the entire rotor. The rotor is viewed looking downstream. Figure 3 is a photograph of the stator within the partially assembled fan stage - again viewing downstream.

Figure 4 is included to show how fan QF-2 relates to other fans tested at the Lewis fan facility. The fan design points are plotted on a matrix of total-pressure rise and tip speed with superimposed lines of constant work coefficient. Fan QF-2 has a moderate work coefficient (about 0.47), indicating intermediate loading compared with other fans represented on this figure.

Figure 5 is an isometric view of the QF-1B fan stage installed in the quiet fan test facility. (Again, the only significant stage differences between QF-2 and QF-1B were direction of fan rotation and nozzle design.) The fan was driven by an electric motor through an inlet drive shaft. A 20-percent-thick, symmetrical, streamlined pylon is clearly visible in this sketch. This pylon was present on all fans tested at the quiet fan facility. This fan stage represents only the bypass flow as there is no core-flow separation as would be required in an engine installation.

The QF-2 fan tests used the variable-area nozzle shown in figure 6(a). The exit area was adjusted by means of a translating tail cone, and the area was measured between the nozzle lip and the surface of the tail cone. The fixed nozzle used for QF-1 and

QF-1B tests is shown in figure 6(b) for comparison. The exit area of the fixed nozzle was measured between the nozzle lip and the cylindrical surface of the inner wall of the flow passage. Mechanical requirements of the variable-area nozzle design resulted in an approximately 155 centimeter (61 in.) longer fan duct than the fixed-geometry nozzle.

TEST FACILITY

Fan QF-2 is shown installed in the quiet-fan facility in figure 1. A plan view of the test site is given in figure 7. The drive shaft extends to the drive-motor building. The drive-motor-building wall was treated with polyeurothane foam to reduce noise reflections. The microphones are located at the fan-shaft elevation (5.9 m (19.3 ft)), on a 30.5-meter (100-ft) radius, and at 10° increments from 10° to 160° from the fan inlet axis. The test area was paved with asphalt.

Aerodynamic Data

A cross section of the QF-2 fan stage showing the axial location and type of instrumentation used is presented in figure 8. Aerodynamic instrumentation included outer-wall inlet-temperature thermocouples, outer-wall static-pressure taps in the inlet duct, total-temperature and total-pressure rakes behind the stator, and total-pressure rakes at the nozzle-exit plane. In addition, acoustic microphone probes were used in the inlet and exhaust ducts. All probes were removed for the far-field noise tests.

The detailed layout of the aerodynamic instrumentation at the four axial measuring stations is shown in figure 9. Six equally spaced iron-constantan thermocouples were located on the bellmouth lip to determine the average inlet total temperature. These thermocouples extended about 1 centimeter (0.4 in.) from the surface to measure the ambient air temperature. Six static-pressure taps were located on the outer wall of the inlet duct and were used for the inlet-mass-flow calculation using the assumption of uniform one-dimensional flow, zero total-pressure loss at the duct station, and a zero wall - boundary-layer thickness. The location of this station was established from a potential-flow calculation. For the inlet-mass-flow calculations the ambient-pressure reading was used for total pressure.

Four total-pressure and total-temperature rakes were used downstream of the stator-blade row to determine the stage-exit mass flow and mass-averaged stage total-pressure ratio. Iron-constantan thermocouples were used on these rakes, which were located so as to minimize stator wake effects. Finally, just downstream of the nozzle exit, three equally spaced total-pressure rakes were used for exit-momentum or thrust calculations.

The aerodynamic data were recorded through a pressure-multiplexing valve, pressure transducer, and data-acquisition network. All temperatures were recorded by the same network, which takes one scan of the aerodynamic pressures and temperatures in approximately 10 seconds. Several consecutive scans were made at each data point, with the raw data samples arithmetically averaged and used to compute the desired flow parameters. The arithmetic average of the computed parameters are presented in this report.

The performance parameters were corrected to standard-day conditions (15° C and 101 kPa (1 atm, 760 torr)).

Acoustic Data

Data acquisition system. - The 1.3-centimeter (1/2-in.) diameter condenser microphones used to make the far-field-noise measurements had sensitivities of -60 decibels relative to 1 volt per 0.1 pascal (1 μbar). The frequency response of the system, as a whole, was flat from 50 hertz to 20 kilohertz.

The acoustic data were reduced both on-line through one-third-octave filters and recorded on magnetic tape for further analysis. Before each set of tests, a pistonphone signal was impressed on each far-field microphone for absolute calibration.

One-third-octave-band-analysis. - The one-third-octave-band analyzer used for on-line data reduction used a 4-second averaging time and stepped sequentially through the angles from 10° to 160°. The 4-second averaging time was selected to accommodate all angles within a 100-second sampling period. The one-third octave data reported are an average of three 4-second integrations. Three 100-second samples were recorded on magnetic tape for each fan speed. Options for the output of the analyzer included an oscilloscope, which presents the sound-pressure-level spectrum, a digital printer, and a digital, incremental, tape recorder.

Results of one-third-octave-band sound-pressure-level (SPL) analysis yielded data taken under ambient conditions of the test day at the microphone locations. The data were referred back to the sound source (i.e., the effect of atmospheric absorption was removed) by computing atmospheric absorption for the test conditions over the propagation path and adjusting the data accordingly. Atmospheric absorption was computed by using continuous frequency-dependent functions derived from reference 5. The application of procedures set forth in reference 5 were not used, as they presuppose a spectrum typical of engine jet noise. For the QF-2 results, which have significant fan noise as well as jet noise, the general shape of the measured spectrum was accounted for, and the one-third-octave-band attenuations were obtained by integrating the continuous absorption functions over each band (ref. 6).

For power calculations the sound pressure levels were presumed to be axisymmetric and were integrated over an enclosing hemisphere. Implicit in this procedure was a perfectly reflective ground plane, in the sense that acoustic intensity was doubled in the far field. No adjustment was made for signal interference effects at the microphones because of ground reflections.

Using data referenced to the source, calculations of atmospheric absorption for a standard day of 15^{o} and 70 percent relative humidity were made, and the data were so adjusted. All one-third-octave-band sound-pressure-level data reported herein are adjusted to standard-day conditions.

The perceived-noise values, calculated (ref. 7) from the standard-day data, take into consideration the frequency-dependent sensitivity of human hearing, thus giving an indication of the human annoyance of the fan noise. For the sideline perceived-noise-level determinations the data were adjusted to a 304.8-meter (1000-ft) sideline.

Narrow-band analysis. - Fine-resolution, constant-bandwidth analyses were made of selected recorded data. These spectra were not adjusted in any way and present the signals at the microphones under test-day conditions. The effective bandwidth of this analysis is inversely related to the total frequency range of the spectrum, with a 32-hertz bandwidth for a 10-kilohertz total range down to a 3.2-hertz bandwidth corresponding to a 1-kilohertz range.

RESULTS AND DISCUSSION

Aerodynamic Performance

The fan operating map of stage total-pressure ratio as a function of corrected inlet mass flow is presented in figure 10 for fan QF-2. (Fan QF-1B results are included for comparison.) The 50.8-centimeter (20-in.) rotor-tip-diameter fan QF-1 model results (ref. 4) were adjusted for scale effects and are also shown on this figure. Neither of the full-scale fans were run at speeds over 90 percent of design (designated takeoff speed). There is good agreement between the full-scale and model results of figure 10, although the agreement is best at speeds below 90 percent of design.

Aerodynamic results for fan QF-1B are available only for 60, 70, and 80 percent of fan design speed. Using the geometry considerations of figure 6, the QF-1B results presented herein are for a nozzle area of 97 percent of design. The design-nozzle area results for fans QF-2 and QF-1B shown in figure 10 suggest that, aerodynamically, the fixed-area nozzle (QF-1B) appears more open, that is, has a higher flow coefficient than the variable area nozzle for the same measured exit area. The performance of fan QF-1B with a fixed nozzle having 97 percent of design area approaches that of fan QF-2 with the variable area nozzle set at 110 percent of design.

Because only the barest amount of aerodynamic instrumentation is used, obtaining good efficiency measurements has frequently been a problem at the quiet fan facility. Values typically are nearly 10 points lower than corresponding results taken at the model facility. A possible source of this error in the full-scale facility may be airflow recirculation. In addition, there was considerable scatter in the measured efficiency results for fan QF-2. Therefore, they are not presented as part of this aerodynamic performance discussion, but they are used in the acoustic performance section to show efficiency trends as an aid in understanding the fan QF-2 acoustic results.

Selected aerodynamic results for fan QF-2 for all tested nozzle areas and fan QF-1B results for the 97-percent-of-design-area nozzle are presented in table II.

Acoustic Performance

The acoustic performance of fan QF-2 will be presented in terms of sound pressure level (SPL), sound power level (PWL), and perceived noise level (PNL). All results are from a one-third-octave analysis, except for a few constant bandwidth SPL spectra. Some comparison will be made with the 97-percent-of-design-area nozzle results for fan QF-1B. The reader wishing to explore these acoustic results further is referred to the complete listing in tables III to VI.

Sound pressure level. - One-third-octave SPL spectra are presented in figure 11 for 90 and 60 percent of fan design speed and for design nozzle area. These speeds are considered to be representative takeoff and approach, respectively. Fan QF-1B results are included for comparison.

At 40° from the fan inlet and 90 percent of design fan speed (fig. 11(a)) the fundamental (BPF) and first overtone (2×BPF) are clearly evident, and there is good agreement of the results for the two fans. However, the broadband results for fan QF-1B are slightly lower than those for fan QF-2. The two fans compare in a similar manner at 120° from the fan-inlet axis (fig. 11(b)), although at this location the differences in broadband level are significant at frequencies above 4000 hertz. These noise differences are thought to relate to differences in the aerodynamic operating point (see fig. 10) (i.e., nozzle performance differences) since otherwise the stages are essentially identical except for direction of rotation.

The 60-percent-of-design-speed results at 40° from the inlet axis (fig. 11(c)) and 120° from the inlet axis (fig. 11(d)) show the results for the two fans to be nearly identical.

The effects of nozzle area variations on the constant bandwidth SPL spectra are presented in figure 12. The SPL spectrum for fan QF-2 at 90 percent of design speed and with design area nozzle is given in figure 12(a). Figure 12(b) shows the corresponding

SPL spectrum for the 110-percent-of-design-area nozzle, and the 120-percent-of-design-area nozzle results are shown in figure 12(c). Figure 12(d) is for fan QF-1B at the same speed and a 97-percent-of-design-area nozzle. All spectra are for 40° from the fan inlet axis. The cutoff theory of reference 8 indicates that the fundamental blade passing tone generated by rotor-stator interaction will not propagate if the number of stator vanes is at least a few more than twice the number of rotor blades. Although the fan QF-2 design satisfies this criterion for the nonpropagation of the fundamental blade-passage tone, this tone is still present in the spectra of figures 11 and 12, thus indicating the existence of another noise generating mechanism - most likely the rotor alone interaction with inlet flow turbulence and distortion.

The fan QF-2 multiple-pure-tone (MPT) generation became increasingly significant as nozzle area increased. Multiple-pure-tone generation is associated with supersonic relative velocity over the rotor blades. Increased nozzle area for a constant speed results in an increased mass flow (see fig. 10), a higher axial velocity component, and, hence, a higher blade relative velocities.

Somewhat more MPT generation is evident for the fan QF-1B results of figure 12(d) than for the design-area nozzle results for fan QF-2 of figure 12(a). Inspection of figure 10 shows fan QF-1B to have the higher mass flow, and therefore a higher relative blade velocity at this fan speed and measured nozzle area. As previously mentioned, the fixed-area nozzle of fan QF-1B appears more aerodynamically open than the variable-area nozzle of fan QF-2 for a given measured exit area.

The overall sound pressure level (OASPL) directivity is given in figure 13. At 60 percent of fan design speed (fig. 13(a)) the front- and rear-quadrant noise peaks are at about the same level. At 90 percent of fan design speed (fig. 13(b)) the OASPL is higher in the rear quadrant. The high noise levels measured 20° and 50° from the fan inlet axis for the fan QF-2 design-area nozzle configuration are not characteristic of the other results in figure 13 and are considered to be due to microphone calibration errors. However, these data do not significantly affect overall noise calculations, which include these erratic points.

Noise components. - As part of the one-third-octave analysis, fan noise components were separated by the following procedure: Beginning with the actual spectrum, an assumed broadband spectrum is drawn by disregarding those data points thought to be influenced by the tone noise. In many cases the tone spike was shared by two one-third-octave filters. The tone contribution to the SPL was found by performing a decibel subtraction of the assumed broadband spectrum level at each frequency from the SPL data as shown in figure 14. All tone contributions, fundamental and overtones, were then added to give the total tone level. Finally, this total-tone value was subtracted from the overall SPL for the spectrum to give the actual broadband sound pressure level. In those instances where the fan operated with a rotor relative Mach number greater than 1.0, the possible existence of significant multiple pure tones in the noise spectra makes the

separation of tones much more difficult. This method of separating the tone and broadband components is an approximation and would be further enhanced by working from a fine-resolution, narrow-band spectrum. However, this greater resolution would also greatly increase the complexity of the calculations. Hence, the one-third-octave spectra were deemed sufficient for this study. A further discussion of the use of narrow-band spectra for analyzing noise components is given in reference 9.

Figure 15 presents tone and broadband SPL directivity obtained with the technique described in figure 14. Front quadrant tone results 30° to 80° from the inlet axis show increasing SPL for fan QF-2 with decreasing nozzle area. No particular trend is evident in the rear-quadrant tone results. The fan QF-1B tone-component results roughly follow the results for fan QF-2 with the 110-percent-of-design-area nozzle as might be expected if equivalent aerodynamic operating conditions (fig. 10) are the controlling parameters.

The broadband SPL component (fig. 15) shows generally high noise levels for the design-area nozzle fan QF-2 results, with the lowest noise levels indicated for the most open nozzle-area results. This is consistent with the concept of broadband noise being proportional to stage loading and nozzle-exit velocity.

Sound power level. - The overall sound power level (OAPWL) is presented as a function of corrected rotor-tip speed in figure 16. Again, the results for fan QF-1B are nearly the same as those for fan QF-2 with the aerodynamically similar 110-percent-of-design-area nozzle.

The results of figure 16 are replotted in terms of tone and broadband components of the OAPWL in figure 17. As in figure 15(b), the fan QF-2 broadband noise level decreases as nozzle area increases. The tone component exhibits a more complex relationship, showing about the same noise level for all tested nozzle areas at lower fan speeds. The levels for the design-area nozzle are essentially constant at 80 percent of design and higher fan speeds. The tone levels are lower for the more open fan QF-2 nozzle at these higher fan speeds. The reduced tone levels for the more open QF-2 nozzle areas probably relates to a transfer of sound energy into MPT generation (see fig. 12), which, by the technique described in figure 14, would not be included in the tone component. This explanation is supported by the continuing increase with fan speed of the broadband results in figure 17, while the fan QF-2 tone results show little increase at the higher fan speeds. This result would be expected if sound energy were transferred from the tone component to MPT generation at the higher fan speeds. There is, however, an inconsistency in this argument with respect to the fan QF-1B tone results, which continue to increase with fan speed. The fan QF-1B constant-bandwidth SPL spectrum (fig. 12(d)) showed more MPT content than did the corresponding design-area nozzle fan QF-2 SPL spectrum (fig. 12(a)). The reason for this difference in the tone generation characteristics of the two fans is not apparent.

Front and rear quadrant sound power levels. - The one-third-octave acoustic results were processed through a computer program that split the sound-power levels into front

and rear quadrant components. The results for 90° from the fan inlet axis were equally shared between the front and rear quadrant for the calculations. The front and rear quadrant PWL spectra are given in figure 18.

The design-area nozzle results for fan QF-2 generally show the higher levels at all frequencies in the front quadrant (fig. 18(a)). The high noise levels measured for this configuration at 20° and 50° from the fan inlet axis (see fig. 13) only partially account for this high PWL. For example, at 6300 hertz, which is in the broadband region of the spectrum, adjusting the fan QF-2 results for the 20° and 50° microphones by substituting SPL values of adjacent microphones only lowers the PWL for that frequency by slightly more than 1 decibel. In general, an increase in nozzle area lowered the front-quadrant PWL across the entire frequency range.

The rear-quadrant results (fig. 18(b)) show a similar nozzle area-noise relationship with the highest PWL associated with the most aerodynamically closed nozzle. A typical jet noise hump is centered at 100 hertz for all configurations.

Stage adiabatic efficiency related to noise. - An increase in measured stage adiabatic efficiency has often been associated with a decrease in the overall sound power level (e.g., see ref. 10). Figure 19 compares the fan QF-2 stage adiabatic efficiency and the overall-sound-power level as functions of nozzle area. The inverse relationship of efficiency to noise is not nearly as convincing as that for the fan of reference 10 and some other fans. This is primarily due to the scatter of the fan QF-2 efficiency measurements. However, the OAPWL results do decrease in an orderly manner with increasing nozzle area for all speeds. Disregarding the 80 and 85-percent-of-design speed efficiency results, there is a trend for increasing efficiency with increasing nozzle area.

Perceived noise. - The perceived-noise level (PNL) is weighted for human hearing sensitivity and therefore gives a more realistic measurement of the noisiness of the fan. The perceived-noise levels along a 304.8-meter (1000-ft) sideline for fans QF-2 and QF-1B are presented in figure 20. The sideline PNL is higher in the rear quadrant for all tested fan speeds. The previously noted high noise 50° from the fan inlet for the fan QF-2 design-nozzle configuration is still evident in this sideline PNL. The sideline PNL at 60 percent of fan design speed is given in figure 20(a); the 90-percent-of-design-speed results are given in figure 20(b). The previously noted noise increase with decreasing aerodynamic nozzle area is evident in these PNL figures.

Figure 21 presents the maximum PNL on a 304.8-meter (1000-ft) sideline as a function of fan speed similar to the PWL presentations of figures 16 and 17. The high noise levels at 50° from the fan inlet for the fan QF-2 design nozzle case had an appreciable effect on the maximum sideline PNL at higher fan speed because of the nonlinear weighting of higher sound pressure levels. Thus, the fan QF-2 design-area nozzle maximum-sideline PNL results are presented in figure 21 in two ways: with consideration of the sideline PNL at all measured locations and with the 50° angular location disregarded. With the PNL results 50° from the fan inlet axis disregarded, the design-area nozzle

QF-2 maximum sideline PNL results are in good agreement with those for QF-1B (97-percent-of-design-nozzle area). The PNL results of figure 21 approximate those the PWL tone component results of figure 17. This is reasonable, since the blade-passage tone for QF-2 occurs in a region of this PNL sensitivity (about 3000 Hz at 90 percent of fan design speed).

In-duct noise. - An acoustic probe using a porous nose cone on a 6.4-millimeter (0.25-in.) diameter microphone was inserted in the inlet duct ahead of the rotor and in the exit duct downstream of the stator as shown in figure 22. Data were taken with these probes at several insertion distances.

Typical 32-hertz-constant-bandwidth SPL spectra for the inlet and exhaust ducts are presented in figure 23. Figure 23(a) presents a typical inlet duct spectrum for the fan QF-2 design nozzle configuration at 90 percent of design fan speed. The spectrum is similar to the corresponding far-field SPL spectrum at 40° from the fan inlet, showing pronounced blade passage and overtones. Of course, the noise levels are much higher in the duct.

The downstream blade passage tone and first overtone (2×BPF) for the same fan conditions (fig. 23(b)) show about the same levels as for the upstream data. However, the broadband levels are considerably higher, such that higher order overtones are not evident at the downstream location.

Figure 24 presents the blade-passage tone SPL as a function of insertion distance from the outer duct wall for 60 and 90 percent of fan design speed and the design-area nozzle configuration. Results are presented at the inlet and exhaust acoustic probe locations. The blade-passage tone SPL were obtained from constant bandwidth spectra.

The 60 percent of design speed results show the most tone SPL variation with insertion distance, with the highest noise level observed near the outer wall. The 90 percent of design speed results show little variation in noise level with insertion distance. Also, there is generally good agreement between corresponding inlet and exhaust noise levels at each fan speed.

SUMMARY OF RESULTS

A 1.5-stage-pressure-ratio, 1.83-meter (6-ft) rotor-tip-diameter experimental fan stage, designated QF-2, was tested for aerodynamic and acoustic performance at the Lewis quiet fan facility. Design features for low-noise generation included the absence of inlet guide vanes, long axial spacing between the rotor and stator blade rows, and selection of blade-vane numbers to achieve duct mode cutoff.

Acoustic and aerodynamic results are included for an essentially identical fan stage except for direction of rotation and nozzle design. This stage was also tested at the outdoor fan facility. Aerodynamic results are compared with those obtained for a

50.8-centimeter (20-in.) rotor-tip-diameter model of the opposite-rotating fan, which was tested in an extensively instrumented indoor facility at Lewis.

The following summarizes the significant results of the fan QF-2 tests:

1. The aerodynamic performance of the variable-area nozzle used on fan QF-2 and the fixed-area nozzle used on the opposite-rotating fan differed for the same measured exit areas. The results implied a higher nozzle flow coefficient for the fixed-area nozzle. Thus, the fixed-area nozzle performed like an oversized variable nozzle. The effective aerodynamic operating point rather than nozzle-exit area determined correspondence of acoustic test points for the two fans.

2. Acoustic probes were inserted in the inlet duct in front of the rotor and downstream of the stator. The measured blade-passage-tone sound-pressure level showed more radial variation at 60 percent of fan design speed than at 90 percent of fan design speed, with the highest noise levels observed near the outer-duct wall at the lower fan speed.

3. Multiple-pure-tone generation became stronger with increased nozzle area. Apparently, increasing the nozzle area produced an increase in the rotor-blade relative velocities, which was large enough to enhance the multiple-pure-tone generation process.

Lewis Research Center,
National Aeronautics and Space Administration,
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APPENDIX A

AERODYNAMIC DESIGN CHARACTERISTICS

The QF-2 fan is essentially identical to the QF-1 fan whose aerodynamic design was discussed in reference 1, with the differences confined to an opposite direction of rotation and a minor difference in the fairing between airfoil and mounting boss contours at the tips of the stator vanes. Much of the design information from reference 1 is repeated here, although it is amplified somewhat to provide sufficient data for the reconstruction of velocity diagrams and blade shapes.

The acoustic-design considerations for this fan, which have already been detailed, led to a number of constraints on the aerodynamic design. The mass-averaged stage-total-pressure ratio of 1.500 was desired with a radially constant rotor-pressure ratio.

The resulting rotor-pressure ratio of 1.541, when obtained with the required low tip speed of 337 meters per second, caused the rotor-hub-section air turning angle to be quite high (59.4°), even with flow path convergence and the relatively high hub-tip radius ratio of 0.50. Rotor-diffusion factors near the hub were high, but were kept within acceptable bounds by the flow convergence. However, the rotor-out-flow conditions caused the stator hub region to operate at inefficiently high inlet-Mach numbers and diffusion factors even with some small amount of diffusion-factor relief from flow convergence in this blade row. The combination of high inlet-Mach number and high diffusion factor at the stator hub produces very high losses in this area. The flow-path convergence in the two blade rows at the hub combined with the long spacing between the rows (dictated by acoustic considerations and in which an essentially constant flow area must be maintained) causes the hub-wall contour to be stopped rather than smoothly curved. Coordinates for this wall and the outer-flow path wall are listed in table VII.

The QF-2 fan was designed without a radially split flow duct behind the rotor so it would match the single-flow duct of the test facility. In an actual engine the flow path would be split to allow a portion of the rotor flow near the hub to be ducted into the core engine. The lack of this flow division imposes both a difficulty in the aerodynamic design and a potential source of a typical noise. The difficulty results from the fact that a single flow path does not allow the designer the freedom to tolerate a step change in the static pressure at the division, which in turn gives the designer less latitude in choosing design parameters near the hub. The result is the previously discussed poor condition of the flow in the stator hub region. The noise measured at the aft end of the fan, which has a single flow path, is slightly higher than the noise of the fan in an actual engine for two reasons: First, the exit airflow is greater than in the engine because some of this flow near the hub would normally have entered the core engine and the greater airflow alone will create additional noise to the rear. The additional noise from this source is

estimated to be less than 1 decibel. Second, this additional flow includes the aerodynamically poor flow from the single-flow-path stator hub region, which could be a potential generator of extra noise. However, because the portion of the total exit mass flow suffering the poor flow conditions is very small, the actual increment of additional noise was estimated to be negligible.

Figure 8 shows a cross section of the fan assembly with several axial reference planes of interest. The inlet face of the rotor assembly in this figure and in table VII, where the leading edges of the rotor blades intersect the hub wall, is at axial station 13.21 centimeters (5.20 in.). The rotor-blade stacking line, a radial line passing through the centers of gravity of the various rotor-blade sections, is at axial station 19.05 centimeters (7.50 in.). The inlet face of the stator-blade assembly is at axial station 75.58 centimeters (30.15 in.).

Because this fan stage did not use inlet-guide vanes, the absolute inlet-flow vector to the rotor was axial. The fan stators were designed to return the airflow at their exit plane to the axial direction over the full passage height. This is typical of fan bypass flow, though not of the flow from normal fan-core stators, which can direct the air to the core engine with some residual swirl. The cutaway view of the fan installation (fig. 5) shows that it is important that the stator discharges axially because of the large downstream pylon. If the flow impinging on this pylon has swirl in it, separation could easily occur, which would cause a restriction in the effective flow area of the exhaust passage, and in turn could possibly cause the fan to stall.

Rotor. - There are 53 rotor blades in the QF-2 (and QF-1) fan, built of aluminum, and having no part-span dampers. A photograph of the rotor assembly is shown in figure 2. The blade sections are all composed of multiple circular arcs. The details of the rotor-blade aerodynamic and section design are presented in parts (a) of tables VIII and IX along flow streamlines that are separated radially by 10-percent increments of flow and that include the inner- and outer-wall streamlines. Definition of the velocity diagram terms will be found in figure 25, and the blade-section geometry terms are defined in figure 26. The symbols used on these two figures and in the design characteristic tables will be found in appendix B for both rotor and stator blades. The sections were designed so that the incoming flow vector relative to the blade was tangent to the suction surface at the leading edge. For the circular arc blade sections used in this design, this causes the incidence angle to be one-half of the blade inlet wedge angle included between the suction and pressure surfaces.

Stator. - There were 112 vanes used in the stator assembly, each made of investment-cast stainless steel. End fixing of the vanes provided proper restraint for stress and vibration considerations, yet allowed re-setting of the blade angles for the adjustment of the fan overall aerodynamic performance, which might be necessary because of swirl in the exit duct. As is the case with the rotor blades, the stator vane sections are composed of multiple circular arcs. A photograph of the stator assembly is shown

in figure 3. Details of the stator vane aerodynamic and section design are presented in parts (b) of tables VIII and IX along extensions of the same streamlines presented for the rotor blades in parts (a). Definitions of the terminology used in the tables are found in figures 25 and 26 and in appendix B.

APPENDIX B

SYMBOLS

A	axial distance between rotor exit and stator entrance
C_p	specific heat
c	blade chord measured along conical stream surface
D	diffusion factor = $1 - \left(V_{rel_2}/V_{rel_1}\right) + \left(\Delta V_T/2\sigma V_{rel_1}\right)$
G	gravitational constant
k	ratio of specific heats
M	Mach number
PR	overall stage total-pressure ratio
s	blade-to-blade spacing in tangential direction on cylindrical surface
T_o	standard-day temperature, 288.2 K (518.7^o R)
U	blade tangential (rotative) velocity
V	velocity
ΔV_T	change in tangential component of velocity across blade row
X	distance from leading edge to camber-line transition point along chord
(XL)	location of camber-line transition point along chord, X/c
Y	distance from leading edge to maximum-thickness point along chord
(YL)	location of maximum-thickness point along chord, Y/c
β	angle between axis and relative velocity vector
$\Delta\beta$	$\beta_{in} - \beta_{out}$
γ	angle between axis and blade chord
θ	angle between axis and tangent to either end of blade camber line
σ	solidity, c/s at mean station radius
τ	blade thickness
φ	included angle of constant turning section of blade camber line
ψ	work coefficient
$\bar{\omega}$	total-pressure-loss coefficient

Subscripts:

abs	absolute component of velocity
in	inlet
LE	leading edge
max	maximum
out	outlet
R	radial
rel	component of velocity relative to rotor blade
T	tangential component of absolute velocity
TE	trailing edge
t	tip
Z	axial direction
1,2	first and second portions of camber-line curvature

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TABLE I. - QF-2 ACOUSTIC AND AERODYNAMIC DESIGN RESULTS

Overall stage total pressure ratio	1.500
Corrected inlet mass flow, kg/sec (lb/sec)	396 (873)
Specific inlet flow, (kg/sec)/m^2 ((lb/sec)/ft^2)	201.7 (41.32)
Stage adiabatic temperature rise efficiency	0.850
Rotor inlet tip speed, m/sec (ft/sec)	337.4 (1107)
Rotor inlet tip diameter, m (in.)	1.824 (71.82)
Rotor speed, rpm	3533.2
Rotor inlet hub-tip diameter ratio	0.499
Stator inlet hub-tip diameter ratio	0.590
Mean radius rotor-stator spacing, a/c, rotor chords	3.6
Rotor total pressure ratio	1.541
Rotor adiabatic temperature rise efficiency	0.909
Rotor work coefficient	0.368
Input shaft power, kW (hp)	16 600 (22 300)
Stage thrust, N (lbf)	105 960 (23 820)
Number of rotor blades	53
Number of stator vanes	112
Blade passage frequency, Hz	3121

TABLE II. - SELECTED AERODYNAMIC RESULTS

Fan	Nozzle area, % of design	Fan speed		Corrected tip speed		Inlet duct Mach number	Stage pressure ratio	Corrected mass flow			
								Inlet		Stator discharge	
		% of design	rpm	m/sec	ft/sec			kg/sec	lbm/sec	kg/sec	lbm/sec
QF-2	100	60	2112	203	664	0.207	1.150	221	488	218	480
		70	2464	236	776	.241	1.209	253	557	257	566
		80	2816	270	886	.278	1.277	292	644	293	646
		85	2994	287	942	.300	1.320	308	679	306	694
		90	3166	304	997	.320	1.365	331	730	332	733
	110	60	2084	203	665	0.224	1.150	239	528	243	535
		70	2430	236	775	.264	1.205	278	613	286	631
		80	2779	270	887	.307	1.274	319	704	327	720
		85	2955	288	944	.327	1.316	338	745	353	778
		90	3119	304	997	.348	1.356	356	785	375	826
	120	60	2089	203	665	0.233	1.145	248	547	257	566
		70	2436	237	776	.274	1.198	289	636	299	658
		80	2784	270	887	.321	1.266	332	731	344	758
		85	2959	287	942	.341	1.299	350	772	362	799
		90	3133	304	998	.368	1.339	373	823	385	848
QF-1B	97	60	2053	203	665	0.220	1.153	235	518	240	530
		70	2396	237	776	.258	1.212	273	602	280	618
		80	2738	270	887	.296	1.278	308	680	318	700

TABLE III. - ACOUSTIC DATA FOR FAN QF-2 WITH DESIGN AREA NOZZLE

[Data adjusted to standard day of 15° C and 70 percent relative humidity; SPL referenced to 2×10^{-5} Pa; PWL referenced to 0.1 pW.]

(a) 60 Percent of fan design speed; fan physical speed, 2112 rpm; fundamental blade passage frequency, 1865 hertz.

FREQUENCY	ANGLE, DEG																AVERAGE SPL	POWER LEVEL (PWL)
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160		
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	70.5	75.0	77.0	68.8	75.0	72.0	70.3	71.3	71.3	72.0	75.3	73.5	76.3	78.8	78.8	80.4	74.8	122.2
63	68.4	79.9	78.9	67.2	74.9	73.2	69.7	68.9	69.7	70.4	74.2	73.4	76.9	79.2	81.2	82.6	75.7	123.1
80	69.8	80.0	72.8	67.5	75.0	69.0	69.3	69.0	71.3	72.3	75.5	77.0	79.0	81.0	83.3	84.6	76.9	124.3
100	73.0	82.0	71.0	69.2	75.2	71.5	72.5	72.5	74.7	75.7	77.5	78.7	80.7	83.2	84.0	84.1	78.3	125.7
125	74.0	79.5	75.0	74.0	77.2	72.7	74.2	75.2	76.7	77.2	78.5	78.7	80.0	81.2	81.5	81.6	77.9	125.3
160	75.0	80.2	75.5	74.2	78.7	73.7	74.7	76.0	75.7	75.7	77.2	76.7	77.5	79.7	79.5	79.4	77.0	124.4
200	76.7	82.0	76.0	73.5	78.5	73.0	72.7	72.2	72.7	73.5	75.0	76.7	78.0	80.2	80.2	78.6	76.5	123.9
250	77.3	80.8	75.8	74.8	77.3	72.3	72.8	72.8	75.0	76.0	77.3	78.0	78.8	80.0	79.5	78.7	76.9	124.3
315	78.5	81.7	78.2	76.5	79.5	74.5	74.2	74.2	74.7	75.5	76.0	77.2	78.2	79.5	78.5	77.1	77.1	124.5
400	80.6	83.1	78.9	77.6	79.9	73.9	74.1	73.9	74.9	76.9	77.9	78.2	78.9	79.6	78.6	77.3	77.9	125.3
500	81.2	84.2	81.0	79.7	82.2	76.2	75.2	75.2	76.0	77.2	78.2	78.7	79.2	80.5	78.7	76.6	79.0	126.4
630	82.7	85.7	82.7	81.7	83.2	77.2	76.5	76.7	77.5	79.0	80.2	80.2	80.0	81.0	79.2	76.3	80.3	127.7
800	84.7	88.7	85.7	84.7	86.7	80.7	79.5	79.2	81.0	82.2	83.2	83.0	84.0	84.2	80.5	78.4	83.4	130.8
1000	88.0	91.7	88.9	86.9	89.0	82.5	81.5	82.4	84.2	85.4	86.7	85.9	87.7	87.2	82.9	81.3	86.4	133.8
1250	88.7	93.5	91.0	88.7	90.0	83.2	82.7	84.0	86.0	88.0	89.0	88.0	89.5	89.2	84.7	83.4	88.2	135.6
1600	91.7	96.7	93.5	91.5	92.5	85.7	84.2	84.7	87.0	89.5	91.0	90.5	91.7	90.2	86.2	84.6	90.4	137.8
2000	96.5	102.5	99.0	96.5	98.5	91.7	89.5	88.7	90.7	93.7	95.2	94.7	96.5	95.0	90.5	88.1	95.5	142.9
2500	90.7	96.0	93.7	92.0	92.5	85.5	84.5	85.2	88.0	90.2	91.7	91.3	92.5	90.5	86.2	83.1	90.9	138.3
3150	91.1	96.4	94.9	93.4	95.1	87.9	85.4	86.4	89.1	91.9	92.9	92.7	93.4	91.1	86.4	83.8	92.4	139.8
4000	91.9	98.2	95.2	93.7	97.4	90.2	85.9	85.9	89.2	91.2	92.7	93.5	93.7	91.9	87.2	84.3	93.4	140.8
5000	92.4	97.2	94.2	92.7	96.4	88.4	84.2	84.9	86.9	89.2	90.7	91.2	92.4	91.4	86.4	83.4	92.4	139.8
6300	91.5	95.5	93.0	91.7	95.2	86.4	82.5	82.8	85.7	88.0	89.0	90.5	91.7	90.7	86.2	82.9	91.7	139.1
8000	89.5	94.5	92.5	91.3	94.0	85.8	80.8	81.3	84.3	86.8	88.3	89.6	90.5	90.5	85.8	82.2	91.4	138.8
10000	86.7	92.2	90.1	88.9	91.9	83.7	78.4	77.9	80.9	83.4	84.9	86.2	87.4	87.1	82.6	78.9	89.7	137.1
12500	84.5	89.5	86.4	85.5	88.4	80.2	74.9	73.4	76.2	78.9	80.4	82.1	83.2	83.7	78.4	75.5	87.4	134.8
16000	80.2	85.9	81.7	80.9	83.7	74.9	68.9	67.6	70.7	73.9	75.9	77.1	79.2	80.4	73.9	72.6	84.9	132.3
20000	76.5	84.0	76.8	76.5	78.6	69.6	63.6	61.6	66.3	69.0	71.8	72.8	73.8	78.0	69.0	71.1	83.8	131.2
OVERALL	102.4	107.7	104.8	103.0	105.5	98.2	95.5	95.7	98.1	100.4	101.8	101.9	103.0	102.0	98.1	96.2	102.7	150.1
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
304.8 METERS	61.8	80.7	83.6	85.2	89.9	84.8	83.8	84.3	86.6	88.8	89.6	88.4	88.1	84.6	77.3	69.3		

TABLE III. - Continued.

(b) 70 Percent of fan design speed; fan physical speed, 2464 rpm; fundamental blade passage frequency, 2176 hertz.

FREQUENCY	ANGLE, DEG																AVERAGE SPL	POWER LEVEL (PWL)
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160		
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	74.1	75.1	78.6	72.8	80.1	74.6	74.3	74.6	75.6	76.1	86.6	77.6	81.3	84.6	84.6	86.4	80.8	128.2
63	70.8	80.0	79.0	71.8	80.0	74.3	72.8	73.0	73.5	73.8	85.8	78.5	82.5	86.0	86.0	88.4	81.3	128.7
80	80.1	80.1	74.3	73.1	80.1	73.6	72.3	73.6	76.1	77.8	86.1	81.8	85.1	87.6	89.3	90.4	83.0	130.4
100	74.6	81.1	73.8	73.1	76.6	73.8	75.1	76.3	78.8	79.8	85.8	85.4	86.6	89.1	89.6	90.0	83.8	131.2
125	76.5	81.3	78.8	76.5	81.3	76.5	78.0	79.0	80.8	81.8	84.8	84.8	86.0	89.3	86.8	88.2	83.5	130.9
160	79.3	83.3	78.5	77.5	82.0	80.3	79.8	80.8	80.0	81.0	83.5	83.3	85.0	87.3	85.3	85.9	82.7	130.1
200	79.5	83.5	78.0	77.5	81.3	77.0	76.3	76.8	76.5	77.8	82.3	81.5	84.8	87.0	85.5	85.2	81.6	129.0
250	80.3	84.3	80.3	78.8	82.0	77.0	76.3	77.5	79.0	81.0	84.0	83.8	85.0	86.5	85.0	84.4	82.3	129.7
315	81.6	85.4	81.9	80.1	83.1	78.6	78.1	78.6	79.6	79.6	83.4	82.6	84.4	85.6	84.1	82.8	82.1	129.5
400	84.5	86.5	83.2	80.7	84.0	78.7	78.0	78.7	79.2	80.5	84.0	83.8	84.5	86.0	83.5	82.1	82.7	130.1
500	84.5	87.5	84.3	83.0	86.3	80.5	79.8	79.3	80.3	81.0	83.5	83.8	84.8	85.3	83.3	81.4	83.3	130.7
630	86.0	88.5	85.8	84.8	87.5	81.3	80.5	80.3	81.8	82.5	84.8	84.8	84.8	85.0	83.3	80.9	84.2	131.6
800	87.8	91.5	88.5	89.0	91.3	84.5	83.3	83.3	84.5	85.8	87.3	87.3	88.0	87.3	84.5	81.7	87.2	134.6
1000	90.6	94.6	91.8	91.4	93.9	87.1	86.1	86.4	87.5	88.5	90.0	89.3	91.3	90.3	85.9	83.9	90.0	137.4
1250	91.0	95.0	93.5	91.5	93.8	87.5	86.5	87.3	90.0	90.8	92.0	91.3	92.5	91.8	87.0	85.7	91.2	138.6
1600	92.5	96.8	94.5	92.8	93.8	87.8	87.0	88.3	91.0	92.5	94.3	92.8	94.5	92.5	88.0	86.7	92.5	139.9
2000	98.1	102.8	101.6	99.6	103.1	97.3	95.6	93.3	95.1	98.3	98.8	98.6	99.1	96.6	92.6	89.4	98.8	146.2
2500	95.1	100.1	99.1	96.8	99.6	93.6	91.6	91.1	93.6	95.8	97.1	96.6	97.6	94.8	90.6	87.7	96.4	143.8
3150	94.8	99.0	97.8	96.5	98.3	91.3	90.0	91.3	93.8	96.5	97.3	96.3	97.3	94.5	89.5	86.7	96.1	143.5
4000	95.2	101.7	98.5	97.2	101.2	94.5	91.5	91.7	94.0	95.7	97.0	97.0	97.7	94.7	90.0	86.6	97.3	144.7
5000	96.3	100.8	98.6	97.3	101.1	94.6	90.8	90.8	92.8	94.6	95.8	96.9	97.1	95.3	90.3	87.0	97.2	144.6
6300	94.8	98.9	97.3	96.5	100.0	93.1	89.5	89.1	91.1	92.9	94.3	95.3	96.5	94.5	89.3	86.0	96.4	143.8
8000	93.3	97.8	96.1	95.3	98.3	91.1	87.8	87.1	89.1	91.3	93.3	94.4	95.1	93.8	88.8	85.1	95.7	143.1
10000	91.2	96.0	94.2	93.2	96.5	89.0	85.2	84.2	86.2	89.0	90.2	91.8	92.2	91.5	86.2	82.2	94.4	141.8
12500	88.3	93.3	91.0	90.8	93.0	85.5	81.5	80.3	82.5	85.3	86.8	88.2	88.5	89.2	83.0	78.6	92.5	139.9
16000	84.2	89.2	86.2	86.7	89.2	81.5	76.5	75.0	77.7	81.2	82.0	84.4	84.4	86.5	78.5	75.9	90.4	137.8
20000	80.6	85.6	82.1	82.3	84.8	76.4	71.4	69.1	74.1	79.6	77.1	81.9	81.6	86.8	73.8	75.2	90.1	137.5
OVERALL	105.3	110.0	108.2	106.7	109.9	103.4	101.1	100.7	102.8	105.0	106.3	106.2	107.1	105.5	101.7	100.3	106.8	154.2
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
304.8 METERS	64.1	82.0	86.5	88.5	94.3	90.0	89.4	89.0	91.1	93.3	94.0	92.6	91.8	87.7	80.5	72.5		

TABLE III. - Continued.

(c) 80 Percent of fan design speed; fan physical speed, 2815 rpm; fundamental blade passage frequency, 2486 hertz.

FREQUENCY	ANGLE, DEG 10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	AVERAGE SPL	POWER LEVEL (PWL)
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	84.8	80.0	81.3	85.3	80.0	83.5	78.5	79.8	82.0	82.3	89.0	83.3	85.0	87.8	90.0	91.2	85.1	132.5
63	74.3	80.0	80.5	76.3	80.0	80.5	77.0	77.3	78.3	79.0	88.0	82.8	85.3	89.8	91.5	93.4	85.1	132.5
80	77.0	80.0	76.0	75.5	80.0	76.5	75.8	77.0	79.3	81.3	87.8	86.5	89.0	92.5	94.5	96.2	87.3	134.7
100	81.3	87.8	79.8	79.6	82.3	77.6	79.8	81.6	84.1	85.6	88.6	89.1	91.1	93.6	95.1	96.0	88.6	136.0
125	82.4	87.9	81.1	80.6	84.1	81.9	82.9	84.9	85.6	87.4	88.1	89.6	90.6	92.4	92.6	93.2	88.0	135.4
160	83.8	88.3	84.1	82.3	86.6	83.1	84.6	85.1	85.6	86.1	87.3	87.6	88.6	90.3	91.6	92.0	87.2	134.6
200	83.8	87.8	85.5	83.0	88.5	82.3	83.0	84.3	82.5	82.8	86.5	87.0	89.5	90.8	91.8	90.4	86.9	134.3
250	85.3	88.1	83.3	81.3	84.6	80.3	80.6	82.1	84.1	85.6	88.1	88.3	89.6	90.8	90.1	89.7	86.6	134.0
315	85.4	88.9	84.6	84.1	87.4	82.9	83.1	83.4	84.1	84.6	86.9	87.1	88.6	90.4	89.6	88.3	86.5	133.9
400	86.8	90.5	85.5	84.8	87.5	82.0	82.3	82.5	84.0	85.0	86.5	87.5	88.8	89.8	88.3	87.4	86.5	133.9
500	87.5	91.0	86.7	86.0	88.7	83.5	82.5	83.7	84.5	85.2	87.0	87.7	88.5	88.2	87.5	86.1	86.7	134.1
630	88.5	92.0	88.0	87.5	89.8	84.8	83.8	83.8	85.8	86.8	87.5	88.1	89.0	88.5	87.0	85.2	87.5	134.9
800	90.3	94.1	90.3	91.1	94.1	87.8	86.1	86.3	88.1	89.6	90.3	89.6	90.6	90.3	87.6	86.2	90.0	137.4
1000	93.1	96.6	94.0	94.1	97.8	90.8	88.8	90.0	91.0	91.7	92.6	92.7	93.7	92.8	89.1	87.4	93.0	140.4
1250	93.0	97.2	95.0	94.7	97.0	91.2	89.7	91.0	92.5	94.5	94.0	94.2	95.7	94.0	88.7	87.9	94.0	141.4
1600	94.4	98.9	96.4	94.9	97.4	91.6	90.9	91.4	94.1	95.9	96.6	95.9	97.1	94.4	90.1	88.7	95.2	142.6
2000	97.1	100.8	98.6	97.1	99.6	94.1	92.8	94.1	96.3	98.8	99.1	98.8	100.6	97.3	92.6	89.7	97.9	145.3
2500	98.8	105.0	104.0	104.3	108.8	104.8	101.3	98.3	99.0	101.3	102.0	101.6	102.5	98.0	94.5	92.4	103.2	150.6
3150	97.5	101.8	99.8	98.1	100.4	94.9	94.4	95.3	97.5	99.8	100.0	99.8	100.8	96.8	93.0	89.7	99.0	146.4
4000	97.3	102.0	99.3	98.5	102.0	95.3	94.0	94.8	97.0	99.5	99.8	99.5	100.3	96.0	91.5	88.9	99.2	146.6
5000	98.3	103.8	102.3	101.6	105.6	99.3	96.3	96.1	98.1	99.3	100.6	101.1	101.3	98.8	93.3	90.7	101.5	148.9
6300	96.6	101.1	99.3	98.6	101.6	94.8	92.6	93.6	94.8	97.2	97.8	98.5	99.7	96.2	91.8	87.9	99.0	146.4
8000	95.3	100.3	98.8	97.6	101.1	94.3	92.1	92.3	93.5	96.6	97.6	98.6	99.6	96.8	91.8	88.3	99.2	146.6
10000	93.2	98.2	96.4	94.9	98.7	91.9	89.4	89.2	90.7	93.7	94.4	95.5	95.7	93.9	88.9	85.5	97.4	144.8
12500	90.8	95.5	93.0	92.3	96.0	88.5	86.0	85.5	87.0	90.3	91.3	92.4	92.9	91.0	86.3	82.5	95.7	143.1
16000	86.2	91.6	88.9	88.4	91.9	84.5	81.2	80.7	83.0	85.9	87.2	88.6	89.6	87.7	82.0	79.6	93.7	141.1
20000	82.4	88.1	84.9	84.6	87.9	80.1	76.3	74.9	78.1	82.6	82.9	84.4	85.1	85.3	77.6	78.1	92.5	139.9
OVERALL	107.3	112.1	110.2	109.6	113.3	108.0	105.4	105.0	106.6	108.7	109.5	109.5	110.5	108.1	105.4	104.6	110.1	157.5
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
304.8 METERS	65.4	84.0	88.7	92.5	98.9	96.0	94.6	94.0	95.4	97.3	97.5	96.2	95.5	90.2	83.6	76.1		

TABLE III. - Continued.

(d) 85 Percent of fan design speed; fan physical speed, 2991 rpm; fundamental blade passage frequency, 2642 hertz.

FREQUENCY	ANGLE, DEG 10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	AVERAGE SPL	POWER LEVEL (PWL)
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	86.0	85.0	82.5	85.0	80.0	84.8	81.5	81.8	81.5	85.5	85.8	87.3	88.3	89.5	91.8	94.7	86.7	134.1
63	76.8	85.0	80.8	77.0	80.0	81.3	78.8	79.5	79.8	81.3	85.0	85.5	88.0	91.5	93.5	97.4	87.1	134.5
80	78.5	92.5	77.5	76.8	86.3	78.0	77.5	78.5	80.5	83.8	87.0	88.3	91.8	93.8	96.5	98.2	89.4	136.8
100	84.3	88.8	86.1	83.1	84.3	83.6	83.6	82.8	85.8	87.6	89.6	90.6	93.3	94.8	97.3	97.9	90.5	137.9
125	84.6	88.1	83.6	82.8	86.3	83.8	84.8	86.1	87.3	89.1	90.3	91.3	92.6	94.1	95.1	95.2	89.9	137.3
160	86.0	91.0	86.8	87.3	89.3	87.3	86.5	87.5	87.0	87.8	89.0	89.5	90.5	92.8	93.8	94.4	89.5	136.9
200	86.3	88.8	84.0	85.8	88.0	84.0	84.5	84.0	84.5	84.8	87.5	88.8	91.5	93.0	93.8	93.2	88.5	135.9
250	85.8	90.3	84.6	84.3	86.6	82.8	83.1	84.6	85.8	88.1	89.3	90.4	91.6	92.6	93.1	92.0	88.7	136.1
315	87.3	90.1	87.6	89.3	92.1	87.3	86.6	86.6	86.1	87.6	88.1	89.8	90.8	92.1	91.8	90.7	89.2	136.6
400	89.3	91.3	87.3	86.8	89.8	84.3	84.0	84.8	85.8	87.0	88.8	90.0	90.5	91.8	91.3	89.9	88.6	136.0
500	88.7	92.7	87.7	87.5	90.7	84.7	84.7	85.2	86.0	87.0	88.0	89.5	90.5	90.5	90.2	88.4	88.5	135.9
630	90.3	94.1	88.6	88.8	91.3	86.1	85.6	85.8	87.1	88.1	88.8	89.8	90.1	90.1	89.3	87.2	89.0	136.4
800	92.0	95.8	91.5	91.0	94.8	88.8	87.8	88.3	89.5	90.5	91.3	91.3	92.0	91.8	89.5	87.6	91.2	138.6
1000	93.9	97.6	94.3	94.4	98.1	92.1	90.4	90.6	92.3	93.0	93.8	93.4	94.5	93.6	90.4	88.0	93.8	141.2
1250	94.2	97.7	95.7	95.0	98.5	92.2	91.5	92.0	93.7	95.5	95.5	95.0	96.5	94.5	90.5	89.1	95.0	142.4
1600	94.8	99.3	96.3	95.3	98.8	92.6	92.1	93.1	95.1	96.6	97.6	96.6	98.3	95.1	90.6	89.7	96.1	143.5
2000	97.3	101.3	98.8	97.0	100.5	94.0	94.0	95.0	97.3	99.5	99.8	99.8	100.8	97.5	93.5	90.7	98.5	145.9
2500	100.3	106.5	106.0	105.0	111.3	104.8	102.3	100.0	101.0	103.5	103.8	103.3	104.0	99.5	95.8	93.9	104.9	152.3
3150	98.2	103.0	100.6	99.1	103.1	97.3	96.3	96.7	99.5	101.5	102.0	101.0	102.5	98.0	94.5	91.4	100.7	148.1
4000	97.7	101.7	99.5	97.7	101.7	95.5	95.2	96.7	98.5	100.7	101.2	100.5	101.0	96.7	93.0	89.9	99.9	147.3
5000	99.5	104.0	103.0	101.3	105.5	98.5	97.0	97.5	99.2	101.2	102.2	102.5	102.3	99.0	94.3	91.4	102.2	149.6
6300	96.8	101.6	99.3	98.1	101.8	94.8	93.6	95.1	96.8	98.8	99.8	100.5	100.7	98.0	93.0	89.7	100.0	147.4
8000	95.8	100.8	99.3	97.5	101.3	94.5	93.0	94.0	95.0	98.0	99.3	100.3	100.8	98.0	93.0	90.0	100.2	147.6
10000	93.5	97.9	96.9	94.9	98.4	91.7	90.2	91.2	92.4	95.2	96.7	97.3	97.4	95.7	90.4	87.2	98.4	145.8
12500	91.1	95.5	93.3	92.3	95.8	88.3	86.3	88.0	89.3	92.3	93.8	93.9	94.3	92.8	87.3	84.8	96.7	144.1
16000	87.0	91.6	89.4	87.7	91.6	83.9	81.7	82.4	84.7	87.9	89.7	90.1	91.1	88.6	83.9	82.6	94.6	142.0
20000	82.8	87.3	85.3	84.1	87.8	79.8	76.8	77.1	80.6	83.8	85.3	86.6	87.3	87.9	79.3	80.6	93.7	141.1
OVERALL	108.2	112.9	111.1	109.9	114.6	108.2	106.6	106.5	108.2	110.3	111.0	111.0	111.7	109.2	107.2	106.8	111.3	158.7
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
304.8 METERS	66.4	85.4	90.1	93.2	100.9	96.5	95.9	95.6	97.2	99.1	99.1	97.8	96.9	91.6	85.3	78.0		

TABLE III. - Concluded.

(e) 90 Percent of fan design speed; fan physical speed, 3167 rpm; fundamental blade passage frequency, 2797 hertz.

FREQUENCY	ANGLE, DEG 10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	AVERAGE SPL	POWER LEVEL (PWL)
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	86.8	85.1	85.1	82.8	80.1	84.8	82.6	83.8	85.1	85.6	91.1	88.6	89.1	91.6	94.6	96.2	88.6	136.0
63	79.1	85.1	82.4	78.9	80.1	82.6	80.4	80.6	81.6	63.1	89.9	86.9	89.6	93.4	96.1	98.8	89.1	136.5
80	80.3	85.1	79.1	78.8	86.3	79.6	79.3	81.1	83.1	85.6	90.3	90.1	93.1	96.3	98.8	100.4	91.3	138.7
100	85.4	86.9	84.9	83.1	88.1	85.1	83.9	84.6	87.6	89.6	91.6	92.9	94.9	98.4	99.6	100.5	92.8	140.2
125	87.4	88.4	86.2	84.7	88.4	84.7	86.4	67.7	89.9	91.2	92.7	93.4	94.4	96.7	97.7	98.3	92.2	139.6
160	87.1	91.3	87.3	86.1	90.8	87.3	87.6	88.8	89.3	90.1	90.8	91.9	92.6	94.8	95.8	96.2	91.2	138.6
200	87.3	90.1	86.6	87.1	89.6	85.6	85.8	85.1	85.1	86.8	89.3	90.6	93.6	95.3	96.1	95.0	90.4	137.8
250	87.1	91.6	86.6	85.8	88.1	84.3	84.6	65.6	88.1	89.8	91.1	92.3	93.1	95.3	95.6	94.5	90.7	138.1
315	89.2	92.2	88.7	88.2	93.4	87.9	87.2	87.7	88.2	88.9	90.7	91.4	92.7	94.4	94.7	93.1	90.9	138.3
400	92.0	93.5	90.8	89.8	92.3	88.0	86.8	88.3	88.0	90.0	91.0	91.8	93.5	94.3	93.8	92.2	91.2	138.6
500	89.8	93.3	90.0	89.3	93.5	88.5	87.8	87.8	88.3	88.8	89.8	91.3	92.0	92.8	92.5	90.7	90.6	138.0
630	90.9	94.4	90.1	89.4	92.1	87.1	87.1	87.1	87.9	88.9	90.1	91.1	91.9	92.1	91.4	89.0	90.2	137.6
800	92.1	97.1	92.9	91.4	95.1	89.9	89.1	89.6	90.6	91.9	91.9	92.6	93.4	93.4	91.4	89.0	92.3	139.7
1000	93.9	97.9	95.2	93.9	97.9	92.7	91.2	91.9	92.7	94.1	94.9	93.9	95.2	94.2	91.7	89.8	94.3	141.7
1250	94.4	98.9	96.6	94.9	98.9	93.6	92.4	92.9	94.4	95.9	95.9	95.6	97.1	94.6	91.6	90.3	95.6	143.0
1600	94.8	99.6	96.8	95.1	99.1	93.8	93.3	93.8	95.8	97.1	98.3	97.1	98.6	94.6	91.8	90.2	96.6	144.0
2000	96.9	101.1	99.1	97.1	100.4	95.1	95.1	96.4	97.9	99.9	100.9	100.1	101.6	97.6	93.9	91.2	99.0	146.4
2500	99.4	105.9	104.6	103.9	107.9	102.2	100.6	98.9	100.9	102.4	103.4	103.2	104.1	98.1	95.4	92.5	103.3	150.7
3150	99.5	106.0	104.8	104.3	107.9	102.3	100.8	99.3	101.5	103.3	103.8	103.6	104.5	99.0	96.5	93.4	103.8	151.2
4000	96.3	101.5	99.3	98.0	101.5	96.5	96.3	97.0	99.0	101.3	102.0	101.1	101.5	97.3	92.8	90.7	100.3	147.7
5000	97.5	103.3	101.0	100.5	103.3	98.0	97.0	98.0	99.8	101.8	102.8	102.8	102.8	99.0	94.3	91.7	101.9	149.3
6300	96.2	101.5	100.0	99.0	102.0	96.1	95.6	96.6	98.1	100.0	101.2	101.6	102.0	98.2	94.3	90.9	101.0	148.4
8000	94.4	100.4	98.9	97.6	100.6	94.4	93.9	94.9	96.4	98.9	100.9	101.7	100.9	97.9	93.4	90.1	100.7	148.1
10000	92.3	98.1	96.1	95.6	98.3	91.6	91.1	92.6	94.1	96.1	97.8	98.7	99.1	96.3	91.6	87.6	99.2	146.6
12500	89.8	95.6	93.3	92.6	95.8	88.3	87.6	89.6	90.6	93.6	95.0	95.7	95.8	93.1	88.6	84.4	97.6	145.0
16000	85.0	91.3	88.0	88.3	91.8	84.6	82.8	84.5	86.3	89.3	91.7	91.9	92.5	89.5	84.7	80.9	95.6	143.0
20000	81.2	87.4	84.7	84.4	87.4	79.5	77.9	79.2	81.9	84.9	87.2	88.5	88.9	85.7	80.9	76.0	94.3	141.7
OVERALL	107.8	113.2	111.3	110.4	113.9	108.4	107.4	107.4	109.1	111.0	112.0	112.0	112.7	110.1	108.9	108.5	111.8	159.2
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
304.8 METERS	67.4	85.4	90.0	93.0	99.4	95.8	95.7	95.9	97.9	99.4	99.7	98.4	97.6	91.8	86.4	79.0		

TABLE IV. - ACOUSTIC DATA FOR QF-2 WITH 110-PERCENT-OF-DESIGN-AREA NOZZLE

[Data adjusted to standard day of 15° C and 70 percent relative humidity; SPL referenced to 2×10^{-5} Pa; referenced to 0.1 pW.]

(a) 60 Percent of fan design speed; fan physical speed, 2081 rpm; fundamental blade passage frequency, 1838 hertz.

FREQUENCY	ANGLE, DEG																AVERAGE SPL	POWER LEVEL (PWL)
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160		
	1/3-OCTAVE BAND SOUND-PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	71.3	75.1	71.1	68.3	69.6	69.6	67.6	70.3	68.6	72.1	72.1	74.3	75.3	75.6	80.8	80.4	73.7	121.1
63	75.5	75.0	74.0	69.5	69.0	70.7	68.7	70.0	67.2	71.2	72.0	74.2	76.2	77.5	82.0	81.9	74.6	122.0
80	75.1	75.1	72.6	67.8	69.6	69.3	67.1	69.3	68.3	73.6	75.1	76.3	78.3	78.8	83.6	83.7	76.0	123.4
100	73.0	78.5	72.8	68.3	72.5	69.5	68.0	72.0	76.5	78.3	77.3	78.8	81.0	79.5	85.0	84.1	78.0	125.4
125	75.8	84.8	74.3	72.3	72.6	72.1	70.6	75.6	74.6	77.6	77.8	79.1	79.8	83.3	81.6	82.4	78.3	125.7
160	78.3	86.1	75.3	72.6	74.8	73.6	72.1	74.8	73.6	75.6	76.1	76.6	77.1	80.6	79.8	79.4	77.2	124.6
200	90.1	93.8	83.8	73.6	85.3	73.1	70.3	71.6	71.6	74.1	74.8	76.1	77.8	77.8	79.8	79.5	81.8	129.2
250	79.5	89.0	78.8	73.3	76.0	72.0	68.5	72.3	71.5	76.0	76.5	78.3	78.8	80.5	79.0	78.7	78.3	125.7
315	77.5	86.0	77.5	74.0	75.5	73.5	69.8	73.8	72.3	74.5	75.0	76.8	77.5	78.3	77.8	77.9	76.7	124.1
400	85.0	92.2	82.7	75.2	83.0	73.0	69.2	73.2	72.0	75.5	76.2	77.0	77.5	78.0	77.2	77.6	80.4	127.8
500	79.2	86.9	78.7	76.2	76.9	73.7	70.4	73.4	72.2	75.4	75.7	76.9	77.9	77.9	76.4	76.6	77.3	124.7
630	80.5	88.3	81.3	77.8	79.5	74.5	71.0	73.8	72.5	76.3	76.5	77.3	78.3	78.5	75.3	75.7	78.4	125.8
800	82.1	86.6	82.1	79.8	79.3	76.8	73.1	75.6	75.1	78.8	79.3	79.3	80.3	80.6	76.1	76.2	79.3	126.7
1000	83.4	86.6	84.6	82.0	81.1	78.6	75.6	78.5	77.8	82.0	81.8	82.3	83.5	82.1	77.4	77.5	81.5	128.9
1250	83.8	87.6	86.1	84.1	82.3	79.6	76.1	80.1	79.3	83.8	84.6	83.8	85.6	83.6	79.6	79.5	83.2	130.6
1600	89.9	93.4	92.1	90.1	89.1	86.9	82.4	84.4	84.6	88.4	88.6	89.6	90.9	87.6	83.1	82.8	88.6	136.0
2000	92.9	98.7	97.4	96.7	94.7	93.4	89.2	89.4	89.9	93.9	94.9	95.4	97.2	93.4	88.2	87.8	94.5	141.9
2500	87.5	91.7	91.2	90.0	87.2	84.2	80.2	83.7	84.5	89.2	90.2	89.8	91.5	88.2	81.7	82.1	88.6	136.0
3150	88.6	92.8	92.6	92.4	89.9	86.9	81.8	85.6	86.1	91.3	92.3	92.6	93.8	89.8	83.1	83.5	90.9	138.3
4000	90.0	94.5	94.0	94.3	93.0	90.6	83.3	86.3	86.3	91.0	91.8	93.1	94.3	90.8	84.5	84.0	92.1	139.5
5000	90.0	93.7	93.2	92.2	92.2	89.4	81.9	85.2	85.2	88.7	90.2	92.0	93.2	90.7	82.9	83.2	91.2	138.6
6300	89.0	92.2	92.2	91.7	91.0	87.1	80.1	83.3	83.8	87.0	88.7	90.8	92.0	90.5	82.5	82.7	90.5	137.9
8000	88.1	91.6	91.6	90.8	89.6	86.1	78.0	81.5	82.0	85.8	87.3	90.2	91.6	89.8	81.6	81.6	90.2	137.6
10000	87.0	89.2	89.7	88.4	88.2	83.9	75.7	78.9	79.1	83.7	84.6	87.6	88.9	88.2	79.4	79.3	89.0	136.4
12500	85.9	88.1	87.3	85.2	86.3	80.1	72.1	74.6	74.9	79.4	80.4	83.8	84.9	85.6	76.6	76.0	87.4	134.8
16000	85.4	86.4	84.7	81.4	83.7	76.2	67.9	68.7	69.5	74.7	76.3	79.0	80.3	84.2	73.7	74.5	86.4	133.8
20000	85.3	86.8	84.3	78.4	82.6	73.1	66.4	64.4	65.1	69.8	71.6	74.5	76.4	83.8	73.1	74.5	88.0	135.4
OVERALL	100.7	105.1	103.4	102.4	101.4	98.6	93.2	95.3	95.6	99.8	100.7	101.8	103.2	100.8	95.8	95.7	101.5	148.9
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
304.8 METERS	60.2	78.7	82.1	84.5	85.9	85.3	81.9	84.1	84.5	88.4	88.6	88.2	88.1	82.8	74.8	68.7		

TABLE IV. - Continued.

(b) 70 Percent of fan design speed, fan physical speed, 2427 rpm; fundamental blade passage frequency, 2143 hertz.

FREQUENCY	ANGLE, DEG 10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	AVERAGE SPL	POWER LEVEL (PWL)
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	72.2	75.0	75.0	73.2	73.5	74.2	72.7	75.2	74.0	76.5	77.5	74.8	80.2	78.0	85.0	85.9	77.9	125.3
63	71.1	75.1	75.6	71.8	72.6	73.1	70.6	74.1	71.3	74.6	77.1	76.1	81.8	78.6	87.1	86.2	78.5	125.9
80	82.5	75.0	76.3	74.3	75.5	77.3	72.0	74.3	74.3	77.8	79.5	79.5	84.3	81.3	89.0	88.1	80.8	128.2
100	73.8	78.0	72.5	72.8	72.0	73.5	72.8	76.8	77.0	80.3	83.0	81.5	86.0	82.0	89.0	88.6	81.7	129.1
125	75.6	83.6	75.6	75.3	76.1	76.8	76.3	79.3	78.6	81.8	83.6	81.8	85.6	81.1	85.1	87.2	81.5	128.9
160	78.3	84.5	77.5	77.5	78.0	79.3	77.0	80.0	78.3	81.3	81.3	78.3	83.8	79.3	85.0	84.7	80.7	128.1
200	78.5	91.0	76.5	76.8	76.3	77.0	74.0	76.5	74.5	77.3	79.3	78.0	84.0	80.0	84.0	83.4	80.7	128.1
250	77.3	87.3	79.3	78.0	77.8	76.5	74.0	77.8	77.5	80.8	81.8	80.3	84.0	79.8	84.5	83.4	80.7	128.1
315	78.3	86.1	80.3	78.6	78.6	78.1	75.6	78.6	77.3	79.8	81.3	79.1	84.1	81.6	85.1	84.0	80.8	128.2
400	79.5	90.0	79.0	78.8	78.3	76.8	74.5	77.5	76.3	79.8	80.5	79.5	83.5	80.8	87.0	88.2	81.8	129.2
500	79.8	86.5	79.8	80.0	79.0	77.5	74.8	77.5	76.3	79.5	80.8	79.3	83.3	79.8	83.5	86.7	80.7	128.1
630	80.5	87.7	81.0	80.7	79.2	78.2	75.0	77.7	76.7	80.5	81.0	79.2	83.2	80.2	83.0	83.4	80.8	128.2
800	83.0	87.3	83.3	83.0	82.0	80.0	76.5	79.8	78.5	82.3	82.8	80.3	85.0	82.0	86.0	86.2	82.6	130.0
1000	84.4	88.1	86.1	85.6	84.4	81.6	78.9	82.4	81.3	84.5	85.4	82.4	87.1	82.6	84.1	86.0	84.3	131.7
1250	84.6	87.8	87.3	86.6	84.6	82.3	79.6	83.1	82.8	86.3	86.8	83.4	88.3	83.8	83.6	85.2	85.3	132.7
1600	86.1	90.2	89.4	88.6	86.8	84.1	81.3	84.9	84.9	88.9	89.7	85.4	90.7	84.6	83.6	84.8	87.4	134.8
2000	94.2	99.2	100.2	101.2	101.4	100.2	93.7	94.9	93.4	98.4	98.9	95.0	100.2	92.4	89.7	89.1	98.3	145.7
2500	90.5	95.0	95.8	96.0	94.8	92.8	87.8	90.3	90.0	94.0	95.3	91.6	96.3	89.8	87.3	87.2	93.6	141.0
3150	89.9	93.9	95.4	94.1	91.6	89.1	85.4	89.9	90.1	94.4	95.4	92.4	96.6	90.4	86.3	86.8	93.2	140.6
4000	92.3	96.8	97.5	97.5	97.1	95.3	88.8	91.8	90.8	94.5	96.3	94.6	98.0	91.0	87.0	87.2	95.6	143.0
5000	92.0	95.7	97.0	96.5	96.7	93.2	87.2	91.2	90.7	93.7	95.0	92.8	97.7	91.8	87.2	87.0	95.1	142.5
6300	91.0	94.7	96.5	96.2	96.0	92.5	86.7	89.8	89.6	92.7	93.7	92.8	96.7	91.5	85.5	86.0	94.8	142.2
8000	89.9	93.6	95.1	95.1	94.1	90.6	84.6	87.4	87.1	91.1	92.4	91.7	95.6	90.9	85.4	85.8	94.0	141.4
10000	88.2	92.5	93.0	93.0	92.2	88.2	82.5	85.5	84.5	88.5	90.2	89.6	93.2	89.5	83.7	84.8	92.9	140.3
12500	86.7	90.6	90.2	90.1	89.2	84.9	79.2	81.4	81.4	85.4	86.9	86.9	89.9	88.2	82.1	82.6	91.4	138.8
16000	85.0	89.0	86.2	87.0	85.8	81.3	74.7	76.3	76.6	81.1	83.1	82.4	86.0	86.1	80.2	82.6	90.0	137.4
20000	84.5	88.2	83.0	83.5	81.9	78.0	72.0	71.7	72.2	76.4	78.4	78.3	82.2	85.5	80.1	82.3	90.1	137.5
OVERALL	101.5	106.0	106.3	106.4	106.0	103.8	98.0	100.6	99.9	103.9	105.0	102.6	106.9	101.4	100.1	100.4	105.0	152.4
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
304.8 METERS	59.9	78.8	84.2	88.4	90.7	90.8	86.4	89.2	88.4	92.5	92.7	88.4	91.6	82.7	78.5	72.8		

TABLE IV. - Continued.

(c) 80 Percent of fan design speed; fan physical speed, 2774 rpm; fundamental blade passage frequency, 2450 hertz.

FREQUENCY	ANGLE, DEG 10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	AVERAGE SPL	POWER LEVEL (PWL)
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	78.3	80.0	85.5	85.3	85.5	79.8	77.0	80.3	81.5	81.0	81.8	83.5	85.3	86.3	91.5	91.9	84.7	132.1
63	72.7	80.0	77.7	75.0	76.2	77.7	74.0	77.5	80.0	79.5	81.0	83.7	85.7	88.5	93.7	94.1	85.0	132.4
80	74.2	83.2	76.5	75.5	75.5	76.7	74.0	77.0	81.0	81.7	84.5	87.0	89.2	90.5	94.7	95.9	86.8	134.2
100	76.8	86.8	79.8	78.3	77.0	79.3	77.3	81.5	85.5	85.5	86.5	89.8	92.0	91.5	95.0	95.9	88.3	135.7
125	80.0	82.5	82.8	80.8	80.3	82.3	80.0	84.8	87.3	86.8	87.8	89.3	90.3	90.8	92.5	93.7	87.6	135.0
160	79.0	83.3	83.0	81.5	82.5	83.3	80.8	85.0	87.0	85.0	85.5	87.0	87.8	89.0	91.3	91.9	86.3	133.7
200	80.0	82.8	84.5	82.0	83.0	81.3	80.3	84.0	84.3	82.3	85.3	86.8	89.0	90.0	90.3	91.4	85.9	133.3
250	80.5	83.5	81.3	80.8	79.0	80.8	77.8	82.0	85.3	85.0	86.3	88.3	89.3	89.0	89.5	89.9	85.7	133.1
315	79.6	82.8	81.3	81.1	81.1	81.8	79.6	82.8	85.1	84.6	85.3	86.8	88.6	88.8	88.3	88.7	85.2	132.6
400	81.2	84.7	81.9	81.7	80.7	80.9	78.2	81.7	84.4	84.7	85.2	86.7	88.2	88.4	87.2	87.6	84.9	132.3
500	81.2	85.0	83.0	82.7	81.5	81.5	78.7	81.7	84.2	84.2	84.5	86.5	87.5	87.2	86.0	86.4	84.5	131.9
630	82.0	92.2	82.7	83.2	82.0	82.0	78.5	81.7	84.0	83.5	84.5	85.7	86.5	86.5	85.0	85.1	84.7	132.1
800	83.7	91.0	85.0	85.0	84.2	84.2	80.2	83.0	85.7	85.7	86.0	86.5	87.5	87.0	85.2	84.9	85.7	133.1
1000	85.8	88.8	87.3	88.0	86.5	85.8	82.3	85.3	88.3	87.3	87.8	87.8	89.5	87.5	85.5	85.6	87.2	134.6
1250	85.5	91.0	87.8	88.0	86.5	85.8	83.0	85.8	89.3	89.3	88.5	88.8	90.0	88.0	88.3	86.4	88.2	135.6
1600	86.9	91.9	89.1	89.4	88.1	87.6	83.9	87.1	91.4	90.6	90.9	90.9	91.9	87.9	86.1	88.5	89.7	137.1
2000	89.2	93.7	92.7	94.0	92.5	91.2	87.7	91.0	94.5	94.2	95.0	94.7	96.5	91.7	87.2	88.1	93.5	140.9
2500	94.0	99.5	102.0	104.5	105.0	103.5	97.5	97.5	100.5	100.7	101.5	100.8	102.5	97.0	92.0	91.7	101.6	149.0
3150	90.8	94.5	94.8	94.3	93.6	91.8	88.6	92.0	97.0	96.2	97.5	97.5	98.8	94.5	88.5	90.9	95.8	143.2
4000	91.0	95.1	95.1	95.1	94.1	92.3	88.8	92.6	97.3	96.8	98.3	98.1	99.0	95.1	89.3	89.0	96.5	143.9
5000	93.5	97.8	100.3	100.5	100.8	98.8	93.8	95.8	99.3	97.8	99.8	100.8	101.3	97.5	91.0	91.5	99.9	147.3
6300	90.5	95.0	96.3	96.0	95.8	93.0	89.0	93.0	96.5	96.2	97.3	98.8	99.4	95.7	88.7	89.9	97.4	144.8
8000	90.1	94.9	96.1	96.8	96.4	93.4	88.9	91.9	95.6	95.4	96.9	98.8	99.4	95.9	88.4	89.4	97.9	145.3
10000	88.6	93.1	93.9	94.4	93.6	90.6	85.8	88.8	92.6	92.6	94.1	96.3	96.4	93.4	86.1	87.5	96.2	143.6
12500	87.1	91.4	91.2	91.6	90.9	87.7	82.1	85.4	89.9	89.7	91.4	93.4	93.8	90.3	83.9	86.1	94.8	142.2
16000	85.1	89.2	87.1	88.7	87.4	83.9	78.4	80.7	85.2	86.1	87.6	89.7	90.4	87.7	82.9	84.4	93.3	140.7
20000	84.8	88.4	83.6	85.4	83.6	80.4	74.9	76.9	81.9	81.6	83.9	85.7	86.6	84.4	83.6	84.8	92.8	140.2
OVERALL	101.6	106.4	107.1	108.2	108.2	106.4	101.4	103.5	107.1	106.7	107.9	108.5	109.5	106.2	104.2	104.9	108.1	155.5
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
304.8 METERS	59.0	78.5	85.6	91.2	93.8	94.3	90.4	92.5	96.0	95.6	95.9	94.8	94.5	88.2	81.5	75.8		

TABLE IV. - Continued.

(d) 85 Percent of dan design speed; fan physical speed, 2948 rpm; fundamental blade passage frequency, 2604 hertz.

FREQUENCY	ANGLE, DEG 10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	AVERAGE SPL	POWER LEVEL (PWL)
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	82.2	80.0	84.7	86.0	84.5	80.7	78.0	80.7	79.7	85.0	83.5	85.2	87.2	89.2	93.7	95.3	86.6	134.0
63	75.7	80.0	79.5	77.2	78.2	78.2	76.2	79.5	77.5	81.2	82.2	84.8	88.5	91.0	96.2	97.1	87.4	134.8
80	76.0	82.3	76.0	77.5	78.3	77.3	75.0	79.5	78.8	83.3	85.8	88.3	91.0	93.3	98.0	98.7	89.3	136.7
100	79.0	80.8	81.8	82.0	78.5	83.3	81.8	83.0	84.3	87.5	89.0	91.0	93.5	94.5	99.3	98.9	90.9	138.3
125	80.0	82.5	83.0	82.3	82.5	83.0	82.0	85.5	85.8	88.3	89.8	91.3	92.8	92.5	96.3	96.7	89.7	137.1
160	83.0	86.0	85.0	86.5	85.0	85.7	83.2	86.0	84.7	87.0	88.2	89.7	91.0	91.5	94.5	95.1	88.7	136.1
200	81.7	85.0	83.0	84.2	85.7	83.0	81.7	83.5	81.5	84.7	86.2	89.0	91.0	92.0	93.5	93.8	87.7	135.1
250	81.8	86.3	83.3	83.0	82.3	82.0	80.0	84.0	83.5	87.5	88.5	90.5	91.5	91.8	92.3	93.4	88.0	135.4
315	80.7	85.7	87.2	88.0	87.2	87.7	83.0	85.2	84.0	88.0	88.0	89.7	91.0	91.2	91.0	91.4	88.2	135.6
400	81.9	84.7	84.4	83.7	83.7	83.2	80.7	83.9	82.9	86.2	87.4	88.7	90.4	90.2	89.9	90.3	86.8	134.2
500	81.9	84.7	84.7	83.7	83.7	82.2	80.4	83.9	82.2	85.7	86.9	88.5	89.4	89.4	88.4	89.3	86.2	133.6
630	83.0	85.2	85.0	83.7	83.0	82.5	80.2	83.2	82.0	85.7	86.2	87.7	88.5	88.0	87.0	87.6	85.5	132.9
800	85.0	87.2	87.2	85.7	86.0	84.5	82.5	85.0	83.7	87.2	87.7	88.5	89.7	88.7	86.5	86.6	86.8	134.2
1000	86.8	88.3	89.8	87.8	89.9	86.8	84.0	87.3	86.0	89.0	89.5	90.0	91.3	89.3	86.8	86.9	88.6	136.0
1250	86.5	89.0	91.2	89.2	90.5	88.0	86.0	87.7	86.7	90.2	90.5	90.2	92.2	89.0	86.5	87.4	89.5	136.9
1600	87.1	90.1	91.8	90.1	92.1	89.3	86.3	89.1	88.3	91.8	91.8	91.8	92.6	88.3	85.1	86.2	90.5	137.9
2000	89.6	92.2	93.4	92.2	93.2	90.7	88.2	91.7	90.9	94.7	94.9	94.9	96.4	91.6	86.9	87.5	93.2	140.6
2500	95.7	101.0	105.2	105.5	109.2	103.7	99.2	100.7	97.2	102.7	102.7	103.3	104.5	97.7	93.0	93.9	103.6	151.0
3150	90.3	96.1	96.3	94.8	97.3	94.3	90.3	94.3	93.5	97.7	99.0	98.3	100.5	95.0	88.7	90.4	96.9	144.3
4000	89.8	93.8	95.3	93.3	95.0	93.0	90.5	94.0	93.5	97.8	99.3	98.8	100.0	95.0	88.0	89.0	96.8	144.2
5000	92.7	98.0	100.5	99.0	101.0	97.5	93.7	97.0	95.7	99.5	101.0	102.1	102.5	97.8	90.0	91.2	100.2	147.6
6300	90.4	95.6	94.9	93.9	95.2	93.0	90.2	94.7	93.1	97.1	98.4	100.2	100.9	96.4	88.4	89.4	97.9	145.3
8000	90.4	95.9	96.3	94.6	95.9	93.6	89.4	93.9	92.9	96.9	98.6	100.7	100.6	97.1	88.1	89.2	98.7	146.1
10000	88.4	93.1	93.3	92.1	93.3	90.3	86.3	91.1	89.8	94.1	96.1	97.7	98.3	94.3	86.1	86.7	97.0	144.4
12500	86.1	91.8	90.1	89.3	90.5	86.9	83.1	88.1	87.4	91.5	93.1	95.7	95.1	90.9	82.6	83.5	95.6	143.0
16000	84.4	89.5	86.7	86.2	87.2	83.9	78.7	83.8	83.0	87.9	89.9	91.4	91.9	87.4	78.7	79.5	94.0	141.4
20000	83.4	88.9	83.4	82.4	84.2	80.4	75.9	79.4	79.1	83.9	86.4	88.3	88.6	84.4	75.7	76.6	93.5	140.9
OVERALL	101.9	106.6	108.6	108.1	110.9	106.6	102.7	105.6	103.9	108.2	109.2	110.1	111.1	107.3	106.5	107.0	109.2	156.6
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
304.8 METERS	60.3	78.8	88.2	91.9	97.3	94.8	92.1	95.0	92.9	97.4	97.2	96.7	96.3	89.3	83.0	77.9		

TABLE IV. - Concluded.

(e) 90 Percent of dan design speed; fan physical speed, 3117 rpm; fundamental blade passage frequency, 2753 hertz.

FREQUENCY	ANGLE, DEG 10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	AVERAGE SPL	POWER LEVEL (PWL)
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	81.3	80.1	82.6	83.6	81.8	83.6	80.1	83.6	82.8	85.3	85.8	87.1	88.3	88.1	96.1	97.4	88.0	135.4
63	76.8	80.0	80.8	79.5	79.8	80.5	77.8	80.5	79.5	83.0	84.5	87.5	90.3	87.5	98.0	99.2	88.9	136.3
80	78.5	83.5	79.0	78.2	79.5	79.2	76.7	81.0	80.7	85.5	86.7	90.7	93.0	92.5	101.0	100.9	91.4	138.8
100	84.0	83.5	83.0	83.0	82.7	82.5	82.5	85.7	84.7	89.7	90.5	92.7	95.2	93.0	100.7	101.4	92.4	139.8
125	83.0	85.2	84.2	83.7	84.5	85.5	84.0	87.7	87.2	91.0	91.7	93.5	94.5	92.0	97.7	98.6	91.4	138.8
160	86.0	87.3	87.0	87.8	86.0	87.5	84.8	88.3	87.5	89.0	89.8	91.8	92.5	90.5	95.5	97.1	90.2	137.6
200	85.0	85.3	83.8	85.0	84.3	84.8	82.0	84.5	83.8	86.3	88.0	90.8	93.0	91.5	94.8	95.2	88.9	136.3
250	83.1	85.6	83.8	83.1	83.1	83.1	81.3	85.8	85.6	89.8	90.8	92.3	93.6	91.6	94.1	94.4	89.5	136.9
315	84.5	85.0	84.8	86.3	85.8	85.8	83.8	87.0	85.8	88.5	89.0	90.8	92.5	90.5	92.8	93.4	88.8	136.2
400	84.0	86.0	86.2	86.2	86.5	86.2	83.0	86.7	85.2	88.7	89.2	91.2	92.5	90.0	91.7	92.6	88.8	136.2
500	84.5	86.5	86.0	88.0	89.5	87.5	85.2	87.2	85.0	88.0	88.7	90.5	91.7	89.5	90.7	90.9	88.7	136.1
630	84.8	85.8	85.0	85.8	85.3	84.8	82.5	85.3	84.0	87.5	88.3	89.8	91.0	88.3	89.5	89.9	87.4	134.8
800	87.2	88.8	88.0	87.8	87.8	86.5	84.8	87.0	86.0	88.7	89.5	90.5	91.7	87.5	88.5	89.6	88.5	135.9
1000	89.6	91.9	91.5	91.8	93.3	90.8	87.8	90.1	88.1	91.1	91.1	91.6	93.4	88.4	88.6	89.3	91.0	138.4
1250	90.3	92.5	93.5	94.0	94.0	93.8	91.0	91.0	89.3	92.5	92.0	92.3	93.5	87.5	89.0	89.4	92.3	139.7
1600	91.2	92.9	95.4	96.2	95.7	94.7	91.7	92.2	90.9	93.2	92.9	93.4	94.2	86.9	87.7	88.6	93.4	140.8
2000	90.2	92.7	93.7	94.7	94.7	93.4	91.2	93.2	92.2	95.4	95.4	95.7	96.9	88.7	88.4	88.6	94.2	141.6
2500	97.0	100.5	104.0	104.0	105.0	102.8	98.3	100.0	98.3	102.0	102.8	103.0	104.8	94.5	93.0	93.2	102.3	149.7
3150	94.4	97.9	101.1	101.1	101.9	100.1	96.3	97.5	97.0	100.5	101.3	101.6	103.3	94.5	93.0	92.2	100.4	147.8
4000	91.0	94.2	96.0	97.2	96.7	96.7	93.7	96.2	95.2	99.0	100.2	99.8	101.2	93.0	89.7	89.9	98.2	145.6
5000	92.9	96.2	98.4	98.7	97.9	96.9	94.2	97.4	96.4	99.7	101.2	102.3	102.9	94.7	90.9	90.9	99.9	147.3
6300	90.7	94.3	96.5	96.7	96.0	94.8	92.5	96.2	95.2	98.9	99.9	101.8	101.7	94.7	90.2	90.4	99.2	146.6
8000	90.1	93.0	95.3	95.8	94.5	93.5	90.8	94.8	94.3	98.3	99.8	101.4	101.8	94.3	89.3	89.3	99.3	146.7
10000	87.4	90.4	92.6	93.4	91.9	90.4	87.6	92.4	91.4	95.6	97.4	99.3	99.1	92.6	87.6	87.7	97.8	145.2
12500	84.7	88.3	89.9	90.8	89.2	87.4	84.7	89.4	88.7	93.3	94.8	96.8	96.6	89.7	84.4	84.8	96.6	144.0
16000	80.7	84.5	86.2	88.0	85.7	83.7	80.5	85.1	85.0	89.7	91.5	93.0	93.5	85.5	80.5	80.8	95.0	142.4
20000	77.9	81.2	83.2	84.7	82.2	79.9	77.4	80.6	80.9	85.6	87.9	89.5	89.9	82.4	77.2	78.1	94.1	141.5
OVERALL	103.4	106.3	108.6	109.0	109.2	107.7	104.3	106.7	105.6	109.2	110.2	111.2	112.2	105.7	108.3	108.9	109.9	157.3
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
304.8 METERS	62.6	79.2	88.0	92.3	95.4	95.5	93.0	95.7	94.5	97.8	97.9	97.5	97.3	87.2	84.3	79.3		

TABLE V. - ACOUSTIC DATA FOR FAN QF-2 WITH 120-PERCENT-OF-DESIGN-AREA NOZZLE

[Data adjusted to standard day of 15° C and 70 percent relative humidity; SPL referenced to 2×10^{-5} Pa; PWL referenced to 0.1 pW.]

(a) 60 Percent of fan design speed; fan physical speed, 2087 rpm; fundamental blade passage frequency, 1843 hertz.

FREQUENCY	ANGLE, DEG 10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	AVERAGE SPL	POWER LEVEL (PWL)
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	68.5	70.0	74.5	69.0	68.8	69.3	67.3	71.3	70.8	71.0	72.0	73.3	75.0	76.0	81.0	80.4	73.7	121.1
63	72.8	75.0	78.5	69.3	68.8	71.3	69.5	69.3	69.8	70.8	72.0	73.5	76.5	77.3	82.3	82.4	75.0	122.4
80	71.2	80.0	73.0	68.2	68.2	69.5	67.5	68.7	70.2	71.5	73.0	76.2	79.5	80.0	84.2	83.9	76.5	123.9
100	70.8	71.0	70.0	69.5	69.0	69.0	68.5	72.0	73.5	74.5	77.0	79.3	81.3	81.0	84.3	83.4	77.4	124.8
125	72.7	75.5	73.2	71.7	72.2	72.5	71.7	74.2	76.2	75.7	77.0	79.5	79.7	78.7	81.2	81.1	76.8	124.2
160	73.8	76.0	73.3	72.8	73.8	74.0	72.5	74.8	75.5	75.0	76.0	77.0	77.5	77.0	80.0	80.2	75.9	123.3
200	76.7	76.7	75.7	74.0	74.2	72.2	70.2	72.2	71.5	72.0	74.0	76.0	78.0	77.7	79.0	78.4	75.0	122.4
250	74.2	79.2	75.2	73.5	72.5	71.5	69.7	72.5	74.2	74.7	76.0	78.0	79.2	77.5	78.2	78.1	75.7	123.1
315	75.2	76.7	75.0	74.0	73.7	72.7	70.7	73.2	74.0	73.5	75.0	76.7	77.7	76.7	77.2	76.9	75.0	122.4
400	76.4	78.2	76.7	74.9	74.2	74.4	70.7	73.2	74.2	74.2	75.9	77.2	77.9	76.9	76.2	76.6	75.6	123.0
500	77.0	78.7	76.5	76.2	74.5	73.2	70.5	72.7	74.7	74.7	76.0	76.7	77.7	76.2	75.2	75.6	75.5	122.9
630	77.5	79.2	78.0	77.2	75.2	74.0	70.5	73.2	74.7	74.5	76.0	77.5	78.2	76.2	75.2	74.8	75.9	123.3
800	79.7	81.7	80.2	78.7	77.7	76.0	72.2	75.5	77.0	77.0	78.0	78.7	80.2	77.5	75.0	75.1	77.8	125.2
1000	82.6	83.6	83.0	81.2	79.6	77.8	74.6	77.3	79.1	79.5	80.0	81.6	82.7	79.3	76.1	76.5	80.1	127.5
1250	82.3	84.8	84.3	82.8	80.8	79.0	74.8	78.5	80.3	81.3	82.0	82.5	84.3	81.3	77.3	76.9	81.5	128.9
1600	88.1	91.6	91.1	90.3	87.8	85.8	80.1	62.3	85.1	86.1	87.1	88.8	90.6	85.1	80.1	81.2	87.5	134.9
2000	95.1	99.1	98.3	97.8	95.1	93.3	87.1	88.6	91.6	92.9	94.1	95.4	97.1	91.9	86.4	87.5	94.6	142.0
2500	86.4	89.2	89.2	88.4	86.7	83.7	78.9	62.9	85.7	86.4	88.2	89.5	90.7	86.4	80.2	80.6	87.3	134.7
3150	87.8	91.3	91.3	90.5	88.3	86.0	80.8	85.0	88.0	88.5	90.3	91.8	92.8	88.5	81.5	82.0	89.6	137.0
4000	89.9	93.7	93.9	93.4	91.4	89.7	82.9	86.4	88.6	88.6	90.4	92.9	94.1	90.9	83.4	83.8	91.5	138.9
5000	89.1	92.1	91.9	91.1	89.9	88.4	81.4	85.4	87.9	86.9	89.6	92.0	92.9	90.4	82.7	82.9	90.5	137.9
6300	87.6	90.2	90.8	90.1	88.8	87.3	79.7	83.9	86.1	85.2	87.9	90.6	92.1	89.3	81.8	81.8	89.7	137.1
8000	85.1	88.9	89.6	88.9	87.4	85.6	77.6	81.3	83.8	83.1	86.1	89.0	90.9	88.1	80.4	80.4	88.8	136.2
10000	82.5	86.0	87.0	86.5	85.0	83.7	75.0	78.2	80.9	82.2	82.4	86.3	87.4	85.4	77.4	77.8	87.1	134.5
12500	79.1	82.6	84.2	83.4	81.9	79.9	71.1	73.9	76.6	78.6	78.9	82.6	83.6	80.9	72.9	73.0	84.8	132.2
16000	75.1	78.9	79.4	79.6	77.9	75.5	66.4	68.7	71.7	73.4	73.4	77.7	79.4	76.6	67.7	68.1	82.3	129.7
20000	73.0	76.3	76.3	75.8	74.5	71.8	63.3	64.5	68.0	69.0	69.0	73.9	75.8	73.0	64.3	65.7	81.5	128.9
OVERALL	99.4	102.9	102.6	101.9	99.9	98.1	91.9	94.8	97.4	97.8	99.5	101.4	102.8	99.2	94.8	95.0	100.4	147.8
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
304.8 METERS	59.2	76.3	81.7	84.8	85.0	85.0	80.4	83.4	86.2	86.8	87.6	88.0	87.9	81.3	73.4	68.0		

TABLE V. - Continued.

(b) 70 Percent of fan design speed; fan physical speed, 2345 rpm; fundamental blade passage frequency, 2150 hertz.

FREQUENCY	ANGLE, DEG																AVERAGE SPL	POWER LEVEL (PWL)
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160		
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	71.0	80.0	77.0	73.0	73.8	73.3	72.3	74.8	76.0	75.0	76.0	78.0	79.8	81.3	85.8	86.4	78.6	126.0
63	71.2	75.0	77.5	71.2	71.2	72.2	70.0	72.7	74.2	74.0	76.0	78.0	81.5	83.2	87.5	88.8	79.6	127.0
80	77.0	81.8	76.8	73.8	75.8	74.0	71.3	74.3	76.5	77.0	79.0	81.5	84.3	85.3	89.5	90.2	81.8	129.2
100	72.8	73.5	73.3	72.5	71.8	74.3	72.0	76.5	79.8	79.3	81.0	83.5	85.5	86.3	89.3	89.7	82.3	129.7
125	76.0	76.8	75.8	76.0	76.0	77.8	75.0	79.3	81.8	81.0	82.0	83.8	85.5	84.8	87.3	86.6	82.0	129.4
160	75.5	79.3	79.2	77.5	78.5	79.2	77.2	80.2	82.0	80.7	81.0	81.5	83.2	83.2	85.5	85.9	81.3	128.7
200	77.0	79.5	77.0	76.8	76.8	76.8	73.8	76.5	78.5	77.0	79.0	80.8	83.0	83.3	84.3	84.9	79.8	127.2
250	76.1	82.6	79.1	77.8	77.3	76.3	73.8	76.8	79.6	80.3	81.1	82.8	83.8	83.6	84.8	84.4	80.8	128.2
315	76.6	81.1	79.8	78.8	78.8	78.3	75.8	78.6	80.6	79.6	80.1	81.6	82.8	82.8	83.1	82.7	80.4	127.8
400	78.2	80.2	79.4	78.4	78.4	77.2	74.7	77.4	79.9	78.9	79.9	81.9	82.4	82.4	82.2	82.3	80.0	127.4
500	78.9	81.4	80.2	79.4	79.4	77.9	76.4	78.2	79.7	78.7	79.9	81.4	82.4	81.4	80.7	81.1	80.0	127.4
630	79.7	81.4	80.4	79.7	78.2	77.9	74.9	77.2	80.4	79.4	79.9	80.9	81.9	81.2	79.9	80.1	79.8	127.2
800	81.3	83.5	82.5	82.0	80.8	79.8	76.5	79.0	82.3	81.0	81.0	82.3	84.0	81.5	80.0	80.2	81.4	128.8
1000	83.0	85.5	84.8	83.8	82.8	81.3	78.5	81.0	84.0	83.0	83.0	84.3	85.3	82.8	80.3	80.1	83.1	130.5
1250	82.7	85.5	85.7	84.7	83.0	81.5	79.0	82.0	85.2	84.5	84.0	85.0	87.0	83.7	80.2	80.1	84.1	131.5
1600	87.6	87.2	87.5	86.5	85.0	83.2	80.5	83.6	87.3	86.3	86.1	86.6	88.6	84.3	79.8	80.2	85.9	133.3
2000	92.4	99.9	101.6	99.9	98.1	98.1	93.9	94.6	96.6	97.1	96.1	96.1	98.4	94.9	88.4	88.5	97.4	144.8
2500	88.2	93.9	95.4	93.9	92.4	92.2	88.2	89.7	92.4	92.9	92.2	92.7	94.7	90.7	84.4	84.8	92.6	140.0
3150	88.3	91.8	92.8	91.5	90.3	88.3	85.5	88.5	93.0	92.3	92.3	93.6	94.8	91.3	83.8	84.2	92.0	139.4
4000	89.4	95.2	96.2	95.7	95.2	93.7	89.4	90.9	94.1	93.6	94.4	95.9	97.2	93.7	85.4	85.8	94.9	142.3
5000	89.4	93.6	94.9	94.1	94.1	92.1	88.6	90.6	93.4	92.6	93.6	95.2	96.9	94.1	85.9	86.3	94.4	141.8
6300	88.6	92.8	94.6	94.1	93.8	90.8	88.0	89.4	92.4	91.4	92.8	94.6	95.8	93.3	84.8	85.3	94.1	141.5
8000	87.7	90.9	92.9	92.4	91.9	89.2	85.4	86.9	89.9	88.9	91.2	93.5	94.7	92.4	83.7	84.0	93.1	140.5
10000	86.5	88.7	91.0	90.5	89.7	86.7	83.2	84.2	87.2	86.7	87.5	90.6	92.0	89.0	81.0	81.3	91.5	138.9
12500	84.9	85.6	87.9	87.1	86.8	83.4	80.1	80.6	83.6	83.4	84.9	87.6	89.1	85.4	77.1	77.5	89.7	137.1
16000	83.9	82.1	83.8	84.1	83.9	79.6	76.4	76.4	79.2	78.7	80.4	83.6	84.9	81.1	72.6	73.1	87.8	135.2
20000	84.2	79.6	80.8	80.8	80.0	76.8	73.3	72.0	75.0	74.5	76.0	79.9	81.0	77.8	69.8	70.2	87.1	134.5
OVERALL	99.6	104.2	105.6	104.5	103.5	102.2	98.5	100.0	102.8	102.5	102.8	104.1	105.7	102.8	98.9	99.3	104.0	151.4
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
304.8 METERS	58.4	77.3	84.6	87.0	88.1	89.3	86.6	88.7	91.4	91.2	90.3	89.9	90.1	84.7	76.7	71.1		

TABLE V. - Continued.

(c) 80 Percent of fan design speed; fan physical speed, 2783 rpm; fundamental blade passage frequency, 2458 hertz.

FREQUENCY	ANGLE, DEG 10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	AVERAGE SPL	POWER LEVEL (PWL)
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	78.5	80.0	86.7	84.0	83.7	79.2	79.5	81.5	76.0	80.2	82.0	82.2	82.5	85.0	92.2	91.6	84.3	131.7
63	73.2	74.9	78.9	75.4	75.2	74.9	76.4	77.7	74.2	77.2	79.9	82.4	81.9	86.9	93.9	93.3	84.2	131.6
80	75.5	81.8	76.0	75.5	74.0	73.3	75.5	77.3	74.0	79.5	83.3	85.5	85.8	89.3	94.3	95.7	85.8	133.2
100	80.7	82.7	81.2	79.4	75.7	76.2	79.7	81.7	77.9	82.7	86.9	88.5	88.9	90.9	94.2	94.6	86.9	134.3
125	80.7	84.7	84.2	83.4	81.9	80.9	81.2	83.7	80.4	84.4	88.2	89.5	88.7	88.9	92.9	92.3	86.8	134.2
160	81.5	84.7	84.7	83.5	82.2	81.5	82.7	84.2	80.7	84.0	86.0	91.5	86.7	88.0	92.2	91.6	86.6	134.0
200	80.8	84.0	85.8	81.3	81.8	80.8	81.5	82.8	79.0	82.5	85.3	91.3	86.3	88.0	90.0	90.6	85.8	133.2
250	80.2	83.2	82.0	80.5	78.0	78.0	80.2	81.7	79.2	83.2	86.2	87.2	86.7	89.0	90.0	90.4	84.9	132.3
315	79.2	82.2	82.2	81.5	79.5	80.2	82.5	82.7	79.7	83.0	85.0	86.5	86.0	88.2	88.2	88.6	84.3	131.7
400	81.0	83.2	81.7	81.7	80.2	79.5	80.7	82.0	78.5	82.5	85.2	86.5	85.7	87.2	87.2	87.4	83.9	131.3
500	81.1	82.6	81.4	82.6	81.1	79.1	80.9	81.9	77.9	82.4	84.1	86.1	85.1	86.1	86.1	86.3	83.4	130.8
630	82.0	83.7	82.7	82.7	79.7	80.5	81.5	82.5	79.0	82.2	84.0	85.5	85.0	85.2	85.0	84.4	83.2	130.6
800	84.0	85.5	85.5	85.2	85.5	83.2	83.5	85.5	81.7	84.5	86.0	86.5	85.2	85.2	84.2	85.4	85.0	132.4
1000	86.8	87.8	88.8	88.8	87.8	87.5	86.0	87.5	84.0	87.0	88.0	87.5	86.8	86.3	84.3	85.4	87.2	134.6
1250	85.9	87.2	87.7	88.4	87.7	85.9	86.5	87.9	83.7	87.7	88.2	88.5	87.4	86.2	84.2	84.3	87.3	134.7
1600	86.6	88.6	89.1	89.3	87.6	87.3	88.3	89.3	85.3	88.6	89.1	89.4	88.8	86.1	83.3	83.5	88.3	135.7
2000	88.6	91.1	92.1	92.4	90.4	90.9	90.1	91.7	87.9	92.4	92.4	92.7	92.4	89.1	84.4	85.5	91.4	138.8
2500	96.7	99.4	102.9	104.4	102.7	104.7	100.7	103.7	96.7	100.9	101.4	98.7	99.7	95.2	92.2	92.6	101.7	149.1
3150	89.5	91.8	92.7	92.7	91.0	91.2	91.2	93.2	90.0	94.0	96.2	95.7	95.4	91.4	85.5	85.9	93.6	141.0
4000	88.6	92.4	92.9	92.7	90.9	90.7	91.2	93.4	90.6	94.4	96.4	96.7	96.2	93.4	86.4	87.1	94.3	141.7
5000	92.8	96.3	99.3	98.8	98.1	97.1	97.1	98.3	93.1	97.1	98.6	99.9	99.6	96.8	89.8	90.0	98.7	146.1
6300	88.6	92.1	93.4	93.1	91.4	90.1	91.1	93.4	90.1	93.9	96.8	98.2	97.4	95.1	87.0	87.5	95.6	143.0
8000	88.4	91.9	94.6	93.6	91.9	91.7	90.9	93.4	89.2	92.9	96.2	96.5	96.7	94.4	87.2	87.7	95.8	143.2
10000	85.2	89.4	91.9	91.4	89.2	87.9	87.4	89.4	86.2	89.9	92.6	95.1	93.9	91.7	84.4	85.2	94.0	141.4
12500	82.6	86.8	88.7	88.2	86.3	85.2	83.9	86.4	82.9	86.4	89.9	92.4	90.9	88.2	80.9	80.8	92.3	139.7
16000	78.9	83.4	85.1	85.2	83.1	81.6	80.4	82.4	78.6	82.9	86.4	88.1	87.4	84.4	76.4	77.2	90.6	138.0
20000	76.5	81.0	82.6	82.6	80.3	78.6	77.6	80.0	75.6	79.6	83.1	85.6	84.3	81.3	74.0	74.9	90.5	137.9
OVERALL	101.4	104.3	106.6	107.1	105.6	106.5	104.3	106.6	101.4	105.4	107.0	107.3	106.9	104.8	103.6	103.9	106.9	154.3
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
304.8 METERS	60.2	77.2	86.0	90.8	91.8	94.6	93.4	96.5	91.0	94.9	95.4	93.4	91.7	86.5	81.0	75.3		

TABLE V. - Continued.

(d) 85 Percent of fan design speed; fan physical speed, 2957 rpm; fundamental blade passage frequency, 2612 hertz.

FREQUENCY	ANGLE, DEG 10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	AVERAGE SPL	POWER LEVEL (PWL)
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	81.3	91.0	86.5	84.8	84.5	80.3	78.0	81.8	78.5	82.8	84.0	85.3	87.0	87.8	93.8	94.2	86.5	133.9
63	74.8	103.5	79.5	77.3	78.3	79.0	76.0	78.3	76.5	80.8	82.3	84.3	88.0	89.8	96.0	95.7	90.6	138.0
80	76.5	82.3	76.8	77.0	76.5	77.8	74.8	78.3	78.5	82.8	86.0	87.8	90.5	92.8	97.8	98.4	89.0	136.4
100	84.5	85.3	82.5	80.5	80.3	82.8	80.5	83.5	83.3	86.0	89.0	90.5	92.8	93.3	97.5	97.4	89.8	137.2
125	80.5	82.5	82.0	81.5	82.5	82.8	81.3	85.8	84.5	88.3	89.3	90.5	91.8	91.8	94.8	95.4	88.8	136.2
160	84.0	88.5	86.5	86.5	85.8	85.8	83.5	86.0	85.5	86.8	88.3	89.5	90.3	91.0	93.5	94.6	88.5	135.9
200	82.3	84.6	83.1	84.6	83.6	83.8	81.3	82.8	81.3	84.3	85.3	88.1	90.3	90.8	92.8	93.0	87.0	134.4
250	81.8	86.1	83.8	82.3	81.3	81.1	79.1	83.8	83.3	86.8	88.3	90.1	91.1	91.1	92.1	92.2	87.5	134.9
315	82.6	84.3	88.6	89.8	88.6	87.3	84.1	86.8	85.1	87.1	87.3	89.3	90.6	90.3	90.8	90.4	88.2	135.6
400	82.0	84.0	84.7	85.5	85.2	84.5	81.0	83.7	83.2	85.7	87.0	89.0	90.0	89.7	89.0	89.4	86.7	134.1
500	82.4	84.2	83.4	83.2	82.4	82.4	79.9	82.9	82.2	85.2	85.9	87.9	88.4	88.4	87.4	88.1	85.4	132.8
630	83.5	84.5	83.8	83.8	83.0	83.5	80.3	82.8	82.3	85.0	85.3	87.3	88.3	87.5	86.5	86.7	85.1	132.5
800	85.2	87.5	86.2	86.5	86.2	86.2	81.5	84.2	84.0	86.5	87.2	88.0	88.7	88.2	86.0	86.6	86.5	133.9
1000	88.0	91.3	90.2	89.8	90.9	92.4	85.7	86.9	86.5	88.5	89.3	90.0	90.5	88.5	86.0	87.2	89.4	136.8
1250	88.3	91.1	92.1	90.1	91.3	94.3	87.1	88.3	86.3	89.3	90.1	90.3	91.3	88.6	85.8	86.7	90.3	137.7
1600	87.8	90.8	91.3	91.3	92.3	94.8	88.6	89.1	88.1	90.3	91.1	90.8	91.8	87.6	84.6	85.5	90.9	138.3
2000	89.4	91.7	91.9	91.9	91.2	91.4	87.9	90.4	89.9	92.4	93.4	92.9	94.7	89.4	85.7	86.3	91.8	139.2
2500	100.0	102.7	104.5	103.0	105.2	103.5	98.7	100.5	98.2	100.7	101.5	101.5	102.2	97.5	92.2	93.1	101.9	149.3
3150	90.6	80.3	94.6	93.6	94.8	94.3	91.1	93.8	93.7	96.0	97.5	97.0	98.8	93.5	87.7	88.2	95.5	142.9
4000	89.2	93.8	94.4	93.2	94.2	94.2	90.9	93.9	94.2	96.4	97.7	97.5	99.4	94.9	87.4	88.1	96.1	143.5
5000	93.1	98.3	98.1	97.8	98.3	97.6	93.3	96.6	95.6	97.8	99.9	101.2	101.9	97.4	89.9	90.1	99.2	146.6
6300	88.3	92.8	93.4	92.6	93.1	92.6	89.6	94.1	93.5	96.3	98.0	99.6	100.5	96.5	88.3	89.3	97.3	144.7
8000	88.9	93.4	94.4	92.4	93.2	92.2	88.7	93.2	92.7	95.9	97.4	99.5	100.2	96.2	87.9	88.5	97.6	145.0
10000	86.0	90.5	91.3	90.5	90.0	89.2	85.5	90.0	89.2	92.7	94.8	96.9	97.5	93.5	85.8	86.1	95.8	143.2
12500	82.5	87.6	88.7	87.2	87.6	85.5	81.7	86.7	86.5	90.0	92.2	94.2	94.0	90.0	81.7	82.9	94.1	141.5
16000	79.2	84.7	84.9	84.4	83.9	82.2	77.9	82.4	82.4	86.4	88.4	90.2	90.7	86.4	77.4	78.4	92.4	139.8
20000	77.0	82.5	82.3	81.8	80.8	78.5	75.3	78.8	79.6	82.5	85.0	87.2	87.6	83.6	75.0	76.2	92.0	139.4
OVERALL	103.2	108.2	107.5	106.5	107.8	107.0	102.6	105.2	104.1	106.7	108.1	109.0	110.0	106.7	105.7	106.1	108.1	155.5
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
304.8 METERS	62.6	80.2	87.5	90.4	94.4	95.3	91.9	94.7	93.4	95.7	96.1	95.4	94.7	88.7	82.2	76.9		

TABLE V. - Concluded.

(e) 90 Percent of fan design speed; fan physical speed, 3130 rpm; fundamental blade passage frequency, 2764 hertz.

FREQUENCY	ANGLE, DEG 10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	AVERAGE SPL	POWER LEVEL (PWL)
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	81.3	80.0	83.5	85.3	80.8	84.8	78.5	82.3	83.0	83.0	86.0	87.3	88.0	89.8	97.0	95.7	88.0	135.4
63	76.5	80.0	80.8	79.0	79.5	79.8	77.5	80.3	78.8	82.3	83.3	86.8	89.8	91.8	98.5	98.4	89.0	136.4
80	78.3	83.1	77.8	78.6	78.3	78.6	76.6	80.8	80.6	85.1	87.3	90.8	92.8	94.1	100.3	99.7	91.0	138.4
100	84.6	84.1	84.1	82.8	82.6	84.1	80.6	84.3	84.8	88.6	90.3	92.6	95.3	95.6	99.1	99.4	91.7	139.1
125	82.8	83.8	83.3	83.6	83.6	84.8	83.3	87.3	86.6	89.8	91.3	92.8	94.3	94.1	97.1	97.7	91.0	138.4
160	83.8	87.0	87.3	86.5	85.8	86.0	84.3	87.5	86.5	88.8	89.3	91.8	92.3	93.3	96.3	95.6	90.1	137.5
200	84.0	85.3	83.8	84.3	84.0	84.3	82.0	84.5	83.3	85.8	88.0	90.5	92.8	93.5	94.5	95.4	89.0	136.4
250	83.0	85.3	83.0	82.5	82.3	82.3	80.5	85.0	84.8	88.3	90.0	91.6	93.3	93.0	93.8	94.7	89.2	136.6
315	85.4	85.6	84.9	85.4	84.9	85.6	83.9	85.9	84.9	87.6	88.4	90.6	92.4	92.1	92.9	93.5	88.7	136.1
400	83.0	85.5	85.7	86.0	85.7	84.0	82.7	85.2	84.5	87.5	88.2	91.2	92.0	92.0	91.7	92.4	88.5	135.9
500	83.5	85.5	86.0	86.0	87.3	85.5	84.0	86.3	84.3	87.3	88.0	90.0	91.0	91.0	90.0	90.4	88.0	135.4
630	84.5	85.2	84.5	85.5	86.0	85.2	82.0	85.5	84.0	86.5	87.2	89.7	90.5	89.7	89.0	89.6	87.2	134.6
800	85.8	88.6	87.1	88.1	87.8	86.8	83.8	86.8	85.6	88.6	89.1	90.6	90.8	90.3	88.6	88.7	88.4	135.8
1000	88.6	91.0	90.2	93.2	94.0	90.7	86.0	89.1	87.8	90.1	90.3	91.6	92.1	90.8	88.8	89.7	90.8	138.2
1250	89.6	92.8	92.3	95.8	98.8	93.6	88.6	90.6	89.1	90.8	91.1	92.1	93.1	91.6	89.1	89.7	93.0	140.4
1600	89.6	91.9	91.9	96.1	96.6	93.1	90.1	92.1	89.9	92.1	92.4	92.6	92.9	89.9	87.9	89.5	92.8	140.2
2000	88.4	91.6	92.4	94.6	94.9	94.1	90.1	92.9	91.6	94.1	94.1	94.7	95.6	91.4	87.4	88.5	93.6	141.0
2500	95.7	101.0	102.5	102.2	102.0	99.2	97.2	98.2	98.5	100.7	101.5	100.8	101.2	96.7	91.7	92.7	100.4	147.8
3150	93.7	98.9	100.7	100.6	100.6	98.3	95.1	97.6	97.6	100.3	101.3	100.4	101.6	97.1	92.3	93.0	99.8	147.2
4000	88.9	93.1	93.6	96.4	96.9	94.4	92.4	95.9	95.7	97.9	99.4	99.5	100.4	95.9	89.7	89.8	97.6	145.0
5000	91.0	94.5	96.0	96.7	97.7	95.5	93.2	97.7	96.7	99.2	101.0	102.3	103.0	98.5	91.0	91.4	99.7	147.1
6300	89.1	92.9	94.1	95.1	95.7	93.7	91.4	96.3	95.6	98.9	100.1	102.0	102.4	98.6	90.9	91.3	99.4	146.8
8000	88.7	92.2	93.4	94.2	93.7	92.2	89.4	94.9	94.7	97.7	99.4	101.8	101.2	97.7	89.9	89.0	99.1	146.5
10000	85.5	89.5	90.8	91.8	90.8	88.7	86.8	92.3	91.8	95.0	96.8	98.9	99.0	95.5	87.5	88.1	97.5	144.9
12500	83.1	86.9	88.2	88.7	87.7	85.9	82.9	88.9	88.7	92.2	94.1	95.9	95.4	91.9	83.9	83.8	95.7	143.1
16000	79.9	83.6	83.9	85.4	84.1	81.9	79.1	84.9	85.4	88.4	90.6	91.9	92.1	87.9	79.6	80.2	94.0	141.4
20000	77.8	80.8	81.4	82.9	81.6	78.6	75.8	81.1	82.9	85.1	88.1	89.2	89.6	85.5	76.8	77.9	94.0	141.4
OVERALL	102.1	106.1	107.2	108.0	108.3	105.9	103.1	106.3	105.8	108.4	109.7	110.7	111.3	108.4	108.0	108.1	109.3	156.7
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
304.8 METERS	61.5	79.2	86.7	91.1	93.8	93.2	91.9	94.6	94.5	96.7	97.0	96.2	95.2	89.7	83.7	78.7		

TABLE VI. - ACOUSTIC DATA FOR FAN QF-1B WITH 97-PERCENT-OF-DESIGN-AREA NOZZLE

[Data adjusted to standard day of 15° C and 70 percent relative humidity; SPL referenced to 2×10^{-5} Pa; PWL referenced to 0.1 pW.]

(a) 60 Percent of fan design speed; fan physical speed, 2043 rpm; fundamental blade passage frequency, 1804 hertz.

FREQUENCY	ANGLE, DEG																AVERAGE SPL	POWER LEVEL (PWL)
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160		
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	71.0	72.5	72.0	71.2	70.2	71.0	71.2	71.7	71.5	73.0	74.2	75.0	76.7	77.5	80.0	81.4	74.6	122.0
63	75.7	74.0	70.2	68.5	72.0	74.2	72.5	72.5	72.0	75.0	73.7	75.0	77.7	79.2	81.7	82.1	75.7	123.1
80	70.4	71.4	68.1	66.9	67.9	69.1	69.4	69.6	71.6	73.9	75.1	77.1	79.9	81.6	83.9	84.3	76.8	124.2
100	71.4	72.4	72.7	70.7	69.7	71.4	71.9	73.4	75.2	76.4	78.7	79.7	81.7	82.9	84.4	85.3	78.5	125.9
125	74.7	76.4	75.9	74.9	74.7	74.2	75.9	76.4	76.9	77.7	79.4	79.7	80.7	81.7	81.9	81.5	78.3	125.7
160	74.7	75.5	75.7	73.7	73.5	74.5	74.5	74.7	76.0	76.0	76.2	76.7	77.5	78.7	79.2	79.4	76.2	123.6
200	75.7	75.4	74.7	72.9	72.2	71.9	72.2	72.7	72.9	73.9	74.9	76.7	78.9	79.9	80.4	79.8	75.8	123.2
250	76.9	77.4	76.7	74.7	73.9	72.4	72.2	73.9	74.7	75.7	77.4	78.9	79.4	79.4	79.2	77.6	76.6	124.0
315	77.9	78.4	78.7	76.9	75.2	73.9	74.7	75.2	74.2	75.7	76.7	77.7	78.7	79.4	79.2	77.5	76.8	124.2
400	80.7	80.4	79.4	77.2	76.7	74.2	74.2	74.7	74.7	76.9	78.4	79.2	80.2	79.2	78.9	77.0	77.7	125.1
500	81.2	82.4	81.2	78.9	76.9	74.7	74.7	75.2	75.7	76.9	77.9	79.7	80.4	79.9	78.4	76.6	78.3	125.7
630	81.9	83.9	82.7	80.4	77.9	75.9	75.9	76.7	76.7	78.2	79.2	80.5	82.2	80.7	78.7	76.3	79.5	126.9
800	84.7	84.9	84.2	82.4	80.7	78.7	77.9	79.2	80.2	81.4	82.7	83.2	83.4	82.4	79.4	77.3	81.7	129.1
1000	86.6	87.5	86.7	83.6	81.6	79.8	80.3	81.1	82.2	83.5	84.5	84.7	86.2	84.1	80.3	79.0	83.7	131.1
1250	88.3	89.0	88.5	85.3	84.0	81.5	81.3	82.8	84.5	86.3	87.0	87.3	88.8	85.8	82.5	79.7	85.9	133.3
1600	93.8	95.1	94.3	91.6	91.1	87.3	85.6	86.1	87.8	89.1	91.3	92.4	93.8	89.6	86.8	82.7	90.8	138.2
2000	96.7	97.7	96.9	94.4	94.7	90.9	88.4	88.9	89.9	91.4	94.2	95.5	96.7	93.2	89.9	84.8	93.8	141.2
2500	92.3	90.8	93.1	91.3	88.8	86.1	84.6	87.8	88.3	90.1	92.6	92.6	92.8	89.1	84.3	81.2	90.5	137.9
3150	92.4	90.9	93.4	92.4	90.9	88.2	85.9	87.2	89.2	90.7	93.4	93.7	93.7	90.4	85.4	81.6	91.6	139.0
4000	92.1	90.1	92.1	92.4	91.6	88.9	83.9	86.4	87.4	88.6	91.6	91.2	92.4	88.9	84.6	80.8	90.6	138.0
5000	90.4	87.4	91.4	91.4	91.2	88.2	81.7	83.7	85.4	88.2	89.9	90.3	90.7	87.9	81.9	80.2	89.7	137.1
6300	89.5	85.3	90.0	90.2	89.0	86.0	80.5	82.1	84.5	86.8	89.5	89.6	91.3	86.8	82.8	79.0	89.2	136.6
8000	88.1	82.6	89.1	89.1	88.7	86.1	78.9	80.4	82.4	84.6	87.9	88.3	88.9	86.7	80.6	78.5	88.5	135.9
10000	85.7	79.1	87.1	87.4	86.7	85.2	77.7	77.9	80.1	83.1	85.6	85.5	84.9	84.6	78.9	75.7	87.3	134.7
12500	84.5	75.6	83.8	86.5	85.3	83.1	75.1	74.6	77.1	79.8	82.1	82.3	82.4	80.8	76.6	73.4	86.2	133.6
16000	81.8	70.0	80.2	82.5	80.8	78.3	70.8	70.5	71.8	74.3	77.8	78.0	78.3	76.6	71.3	69.7	83.8	131.2
20000	78.8	65.0	76.3	78.6	77.3	73.3	66.6	66.6	67.0	69.5	72.6	73.6	73.8	72.6	67.1	66.4	82.4	129.8
OVERALL	102.5	102.1	102.9	101.7	100.9	98.0	94.8	96.1	97.4	99.1	101.5	102.0	102.9	99.9	96.8	94.7	101.0	148.4
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
304.8 METERS	62.0	76.1	82.0	83.6	85.7	84.2	83.0	84.6	86.0	87.3	89.0	88.9	88.3	83.0	76.5	67.3		

TABLE VI. - Continued.

(b) 70 Percent of design speed: fan physical speed, 2386 rpm; fundamental blade passage frequency, 2107 hertz.

1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS

FREQUENCY	ANGLE, DEG 10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	AVERAGE SPL	POWER LEVEL (PWL)
50	75.4	73.9	75.6	75.6	74.1	75.6	75.4	76.9	76.1	78.4	80.1	79.4	81.4	82.6	85.1	87.0	79.6	127.0
63	73.4	74.9	73.7	72.9	73.2	73.2	74.4	75.2	75.7	75.9	78.9	79.2	82.9	65.2	86.7	88.3	80.2	127.6
80	73.9	74.4	74.4	74.4	74.7	74.7	74.7	74.4	76.4	78.7	81.2	82.7	85.9	86.7	90.2	90.5	82.6	130.0
100	75.6	75.4	75.6	74.9	74.4	75.9	76.4	78.1	80.1	81.4	83.9	85.1	87.1	88.4	91.1	91.0	84.1	131.5
125	77.9	79.4	79.4	79.1	78.6	78.9	78.9	80.4	81.6	83.4	84.9	84.4	86.1	87.1	88.4	88.8	83.6	131.0
160	79.1	78.9	79.4	78.1	78.9	78.6	79.9	80.1	81.1	81.4	82.1	82.2	83.1	84.4	85.9	85.8	81.7	129.1
200	79.9	80.9	79.2	77.9	76.7	77.2	76.9	77.4	77.9	78.9	81.2	81.7	84.7	85.2	86.9	85.6	81.3	128.7
250	80.9	81.4	80.1	78.4	77.6	77.6	77.1	78.1	79.6	80.6	82.9	83.6	84.6	84.4	85.6	84.2	81.6	129.0
315	81.5	81.5	80.7	79.7	79.5	78.7	78.7	79.7	80.2	80.5	82.5	83.2	84.0	84.5	85.5	83.1	81.7	129.1
400	83.4	81.9	82.4	80.6	79.1	78.4	77.6	78.9	80.1	80.9	82.4	83.1	84.4	83.9	84.4	82.5	81.7	129.1
500	84.4	83.9	83.2	81.4	80.4	79.2	78.9	79.2	80.2	81.2	82.4	83.4	85.2	63.7	83.7	81.5	82.1	129.5
630	84.2	85.4	84.7	83.2	80.7	79.9	79.2	79.9	81.7	82.2	82.9	84.2	85.9	83.7	82.7	80.8	82.8	130.2
800	86.6	86.4	86.1	84.6	82.6	81.4	81.1	61.9	83.6	84.9	85.6	86.1	86.9	84.6	83.4	81.0	84.5	131.9
1000	88.4	87.9	87.9	55.7	84.2	83.2	82.7	83.7	85.6	66.3	87.1	87.7	88.8	85.2	84.2	81.8	86.1	133.5
1250	89.3	89.5	90.0	87.3	85.8	84.8	84.3	85.3	88.3	89.0	89.8	89.8	92.3	86.8	85.3	82.2	88.4	135.8
1600	92.1	92.6	92.4	90.1	88.5	87.3	86.4	88.1	90.9	92.1	92.9	92.7	94.6	89.1	86.9	84.0	91.1	138.5
2000	97.9	99.2	100.2	99.2	100.7	98.9	95.7	95.2	95.4	96.2	97.9	101.7	101.7	95.9	92.7	89.1	98.7	146.1
2500	95.3	94.3	96.0	94.0	93.5	91.8	89.8	92.3	92.8	95.3	96.0	96.8	97.3	92.3	88.8	86.0	94.6	142.0
3150	95.2	94.4	94.9	94.2	92.9	90.9	89.4	91.2	93.4	94.7	96.9	96.2	96.7	91.7	88.2	85.3	94.5	141.9
4000	94.6	94.6	95.1	95.4	95.4	94.4	90.4	91.6	92.4	93.6	95.9	95.7	96.4	91.4	87.9	84.6	94.8	142.2
5000	92.9	91.9	94.4	94.7	94.2	92.7	87.9	88.9	90.9	93.7	93.9	94.5	94.7	90.2	85.4	83.6	93.7	141.1
6300	93.2	91.2	93.2	94.5	92.7	92.0	87.7	87.6	90.0	92.1	93.2	93.8	95.0	89.2	86.5	82.7	93.5	140.9
8000	91.3	89.0	92.6	92.6	91.8	91.6	85.5	85.3	87.8	89.5	92.3	92.9	92.8	89.3	84.3	82.1	92.7	140.1
10000	89.7	85.6	90.4	91.2	90.7	89.7	83.9	82.9	85.7	88.2	89.9	90.1	89.6	87.4	82.4	79.8	91.6	139.0
12500	88.5	82.6	88.0	91.0	89.2	88.2	81.5	80.5	83.3	85.6	87.3	87.9	87.0	85.0	80.7	78.2	91.1	138.5
16000	85.5	77.5	84.2	87.2	84.7	84.2	78.0	77.0	78.5	80.5	82.8	83.9	84.2	81.2	75.8	74.7	89.0	136.4
20000	83.0	73.1	80.6	83.3	82.1	80.3	73.6	72.8	73.8	76.1	77.7	79.9	79.6	77.1	72.6	71.4	87.8	135.2
OVERALL	104.5	104.2	105.4	104.9	104.8	103.4	100.2	100.8	102.2	103.7	105.2	106.3	106.9	102.6	101.0	99.7	105.0	152.4

SIDELINE PERCEIVED NOISE LEVELS

DISTANCE	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
304.8 METERS	63.6	77.7	84.6	87.3	90.2	90.4	88.9	89.8	90.9	91.9	92.8	93.8	92.7	85.8	80.3	71.9

TABLE VI. - Continued.

(c) 80 Percent of design speed; fan physical speed, 2729 rpm; fundamental blade passage frequency, 2410 hertz.

FREQUENCY	ANGLE, DEG 10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	AVERAGE SPL	POWER LEVEL (PWL)
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	83.0	78.0	79.2	84.2	81.2	86.0	83.2	86.5	83.5	82.5	84.7	84.2	86.2	89.5	90.5	92.3	85.8	133.2
63	77.0	77.0	77.7	77.7	77.5	78.0	79.0	79.2	80.5	81.2	82.2	84.5	87.5	91.0	92.5	94.1	85.5	132.9
80	77.9	77.4	76.7	75.9	75.9	76.9	77.2	78.7	81.7	82.7	84.9	86.7	90.2	92.2	94.4	95.6	87.1	134.5
100	81.5	80.5	81.7	80.0	79.2	80.5	81.2	83.7	85.2	87.2	88.2	89.5	92.7	94.5	96.2	96.4	89.4	136.8
125	82.4	83.9	84.4	81.9	82.4	83.4	83.9	85.9	86.2	87.4	89.2	89.9	90.9	92.4	93.2	93.6	88.4	135.8
160	84.0	83.5	83.7	83.0	83.2	83.5	83.5	85.2	85.7	86.0	87.0	87.2	88.2	90.0	91.2	90.8	86.6	134.0
200	83.5	84.0	84.5	84.0	85.0	84.2	81.5	83.0	83.5	83.7	86.0	87.5	89.2	91.2	92.0	91.1	86.7	134.1
250	84.0	85.0	85.0	86.2	87.5	86.2	81.5	84.0	84.7	85.7	87.5	88.5	89.2	90.7	93.2	89.6	87.1	134.5
315	84.7	84.0	84.0	83.0	83.2	82.5	82.7	84.0	84.2	85.5	86.2	87.2	88.7	90.2	90.0	88.4	86.1	133.5
400	85.6	84.4	85.1	84.1	84.1	82.1	82.1	83.1	84.1	85.4	86.4	87.6	88.4	89.4	89.1	87.3	86.0	133.4
500	86.6	85.4	86.9	86.4	84.9	83.1	82.9	83.4	83.9	85.6	86.4	87.4	88.4	88.6	87.9	86.3	86.1	133.5
630	86.4	86.4	86.9	86.7	85.2	83.7	83.4	84.2	84.7	85.9	86.9	87.7	88.7	88.2	86.9	85.1	86.3	133.7
800	89.3	87.5	88.5	89.0	86.5	85.5	85.3	85.5	86.5	88.0	88.8	89.5	89.8	88.3	87.0	85.4	87.8	135.2
1000	90.1	88.6	89.3	88.8	87.3	86.3	86.8	86.8	88.1	88.8	89.3	90.3	90.6	87.8	86.6	85.2	88.5	135.9
1250	91.0	90.5	90.5	89.8	88.3	86.5	86.5	87.0	90.0	91.0	91.8	92.6	93.5	89.0	87.5	85.2	90.3	137.7
1600	93.2	92.7	93.2	92.5	91.0	89.5	89.0	90.2	93.7	94.2	94.7	95.5	95.5	90.7	88.5	86.9	93.0	140.4
2000	96.0	95.7	96.5	96.7	95.5	94.0	92.0	94.2	96.0	97.0	98.0	99.0	98.2	93.0	90.2	88.4	96.3	143.7
2500	102.1	101.4	103.9	105.9	105.9	104.4	101.1	100.6	99.9	100.9	102.1	104.4	103.4	98.1	95.4	92.8	103.0	150.4
3150	97.1	95.6	96.6	96.1	94.8	92.8	92.3	94.1	97.0	98.0	99.7	99.4	99.1	93.6	90.6	88.5	97.1	144.5
4000	94.7	94.2	95.4	95.9	94.2	91.9	90.4	93.9	95.7	96.4	98.2	97.5	97.4	91.9	89.4	86.9	96.0	143.4
5000	95.5	95.0	98.8	100.0	99.3	97.3	93.8	94.2	96.0	97.8	98.0	98.8	98.5	93.3	89.0	88.2	98.2	145.6
6300	94.5	92.9	94.9	95.9	93.6	92.6	90.1	91.9	94.1	96.1	96.8	96.9	96.8	91.3	88.6	86.1	96.0	143.4
8000	93.1	90.6	94.9	95.4	94.3	93.6	89.1	89.9	92.4	94.1	96.4	96.5	95.9	91.6	87.6	86.0	96.0	143.4
10000	91.0	87.7	92.4	93.5	92.2	92.2	87.4	87.7	90.2	92.7	93.9	93.3	92.7	90.0	85.2	83.0	94.7	142.1
12500	89.8	84.6	90.0	93.0	91.0	89.7	85.0	85.8	88.0	90.3	91.5	91.7	90.8	88.0	83.8	81.9	94.2	141.6
16000	86.8	80.1	86.6	89.3	87.1	86.6	81.8	82.1	84.2	85.9	88.1	87.8	88.1	84.6	79.6	79.1	92.5	139.9
20000	83.4	74.1	82.9	85.6	83.6	82.1	77.6	78.6	79.3	81.6	82.9	84.1	83.6	81.1	76.1	75.9	91.1	138.5
OVERALL	106.8	105.8	107.9	109.1	108.5	107.1	104.2	104.9	106.1	107.3	108.5	109.3	109.0	105.8	104.8	104.3	108.3	155.6
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
304.8 METERS	65.3	79.2	87.7	92.8	95.0	95.2	93.9	94.8	95.5	96.3	96.9	97.3	95.2	89.0	83.6	75.9		

TABLE VI. - Concluded.

(d) 90 Percent of design speed; fan physical speed, 3071 rpm; fundamental blade passage frequency, 2712 hertz.

FREQUENCY	ANGLE, DEG 10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	AVERAGE SPL	POWER LEVEL (PWL)
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	84.5	80.8	84.3	88.3	86.5	86.5	86.3	87.5	87.3	88.5	88.5	89.8	91.0	92.5	95.5	96.6	89.7	137.1
63	80.8	82.3	81.5	81.5	81.8	82.0	83.3	83.3	83.5	84.5	86.8	88.5	91.8	94.0	97.8	99.1	89.9	137.3
80	82.0	82.5	79.5	80.0	80.0	81.0	81.5	82.7	84.5	86.2	89.5	91.0	94.2	97.5	99.5	101.6	92.1	139.5
100	85.7	84.0	84.7	84.5	84.7	87.0	86.0	88.2	89.7	90.2	94.0	94.8	96.5	98.7	101.2	102.1	94.2	141.6
125	88.2	86.5	87.5	86.7	86.2	87.5	87.5	89.5	90.0	91.5	93.5	94.3	95.5	97.5	99.5	98.4	93.1	140.5
160	88.0	87.7	87.0	86.7	87.0	87.7	88.7	88.7	89.5	90.2	91.5	91.5	93.0	95.0	96.2	96.6	91.2	138.6
200	88.0	86.7	87.0	86.0	86.0	86.2	86.2	86.0	86.7	88.0	90.2	91.7	94.0	96.2	97.5	96.4	91.1	138.5
250	87.0	86.5	87.0	86.7	84.7	85.5	85.5	86.7	88.2	90.0	91.7	93.2	93.5	95.0	95.7	94.6	90.8	138.2
315	88.1	87.3	88.1	86.8	86.8	87.1	87.3	88.1	88.3	89.3	91.3	92.1	93.6	94.6	95.6	93.7	90.7	138.1
400	87.9	87.4	87.9	86.4	87.2	86.7	86.2	87.2	88.4	89.4	90.9	92.2	93.4	94.2	94.4	92.1	90.4	137.8
500	87.9	88.2	88.7	86.9	87.4	87.7	86.4	87.7	87.9	88.9	90.2	91.7	92.7	92.9	93.2	90.8	89.9	137.3
630	87.5	88.5	89.0	87.8	88.8	90.0	87.3	88.8	88.8	89.3	90.5	91.8	92.5	92.5	91.5	89.6	90.1	137.5
800	89.8	89.5	90.0	89.8	89.5	90.3	88.5	89.5	89.0	90.5	91.3	92.8	92.8	92.8	91.3	89.2	90.8	138.2
1000	90.1	90.6	91.1	92.8	92.3	92.8	90.8	89.8	90.1	90.8	91.8	92.6	92.8	91.3	90.8	89.0	91.6	139.0
1250	91.9	91.4	92.4	92.1	92.4	93.4	90.6	90.4	91.9	92.6	93.4	94.9	93.9	91.6	90.4	88.0	92.6	140.0
1600	92.7	92.7	93.7	93.2	94.5	94.7	92.0	93.0	94.5	95.0	95.5	97.2	95.0	92.0	90.5	88.4	94.4	141.8
2000	94.2	93.5	95.0	94.0	94.5	93.5	92.0	94.7	95.7	97.0	98.0	100.0	96.5	93.0	91.0	89.1	96.0	143.4
2500	102.4	102.4	105.9	106.4	106.9	104.7	101.2	101.6	100.4	102.6	104.2	106.7	104.7	99.4	94.4	93.8	104.2	151.6
3150	98.1	97.6	100.6	100.3	101.1	98.8	96.6	97.1	98.3	100.3	102.0	102.6	101.1	97.3	93.0	91.7	100.2	147.6
4000	93.5	92.5	94.7	94.8	93.7	93.5	92.2	95.5	96.5	98.0	100.0	99.1	97.7	92.7	90.7	89.0	97.0	144.4
5000	95.8	93.5	98.3	98.8	97.3	96.0	93.8	95.3	97.0	99.5	100.3	100.8	98.5	93.8	89.5	89.5	98.7	146.1
6300	93.4	90.9	94.9	95.1	93.1	93.0	91.6	94.0	96.0	98.0	99.0	98.6	98.3	92.8	90.6	88.3	97.4	144.8
8000	92.2	88.7	95.0	94.0	93.2	93.6	90.2	92.7	94.5	96.7	99.0	99.3	97.0	92.9	89.0	88.0	97.5	144.9
10000	89.5	85.2	91.7	92.0	90.5	91.5	88.5	90.2	92.5	95.2	96.2	95.9	94.2	91.5	87.5	86.1	96.0	143.4
12500	88.3	81.9	89.7	91.3	89.8	90.1	86.3	88.6	90.1	93.3	94.6	94.8	92.3	89.8	86.1	85.2	95.8	143.2
16000	85.4	77.2	85.8	87.8	85.8	86.1	83.4	85.1	86.3	88.7	90.8	90.8	89.9	86.6	82.1	82.1	94.0	141.4
20000	82.4	72.2	81.9	83.9	82.4	82.1	79.4	81.1	81.9	84.4	86.4	87.7	85.6	83.2	78.7	79.2	92.8	140.2
OVERALL	106.9	106.2	109.2	109.5	109.6	108.2	105.7	106.8	107.4	109.2	110.7	111.8	110.6	108.8	109.0	109.0	110.0	157.4
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
304.8 METERS	66.4	80.4	89.4	93.5	96.4	96.7	95.2	96.6	96.8	98.3	99.2	99.9	96.9	91.5	85.9	79.5		

TABLE VII. - NACELLE FLOW PASSAGE WALL COORDINATES

Axial station[a]		Outer diameter		Inner diameter	
cm	in.	cm	in.	cm	in.
-25.4	-10	187.2	73.70	71.07	27.98
-7.62	-3	187.2	73.70	80.37	31.64
0	0	187.2	73.70	88.40	33.23
7.62	3	186.7	73.50	88.47	34.83
13.34	5.25	183.7	72.34	91.57	36.05
24.76	9.75	175.3	69.00	96.72	38.08
30.48	12	173.4	68.26	98.70	38.86
38.10	15	172.5	67.93	99.75	39.27
50.80	20	↓	↓	100.5	39.57
63.50	25			100.5	39.57
71.12	28			100.9	39.74
76.20	30			101.8	40.08
83.31	32.8			104.6	41.20
91.44	36			106.4	41.89

[a]Reference plane for axial positions shown on fig. 8.

TABLE VIII. - AERODYNAMIC DESIGN CHARACTERISTICS OF QF-1 AND QF-2

(a) Rotor

Radial station	Radial location of section				Axial velocity, V_z				Absolute tangential velocity, V_T				Radial velocity, V_R				Blade tangential velocity, U				Relative inlet Mach number, M_{IN}	Diffusion factor, D	Pressure loss coefficient, $\bar{\omega}$		Total pressure ratio	Relative air turning angle, $\Delta\beta$	
	Leading edge		Trailing edge		Inlet		Outlet		Inlet		Outlet		Inlet		Outlet		Inlet		Outlet				Profile	Shock		Radians	deg
	cm	in.	cm	in.	m/sec	ft/sec	m/sec	ft/sec	m/sec	ft/sec	m/sec	ft/sec	m/sec	ft/sec	m/sec	ft/sec	m/sec	ft/sec	m/sec	ft/sec							
1	91.21	35.91	88.29	34.76	157.79	517.69	167.87	550.74	0	0	149.85	491.62	-55.55	-182.25	-43.44	-142.52	337.48	1107.21	326.67	1071.76	1.136	0.478	0.153	0.035	1.541	0.329	18.84
2	87.40	34.41	84.99	33.46	177.33	581.80	175.23	574.90	↓	↓	139.52	457.73	-47.83	-156.93	-34.77	-114.07	323.38	1060.96	314.45	1031.67	1.127	.455	.071	.035	↓	.287	16.46
3	83.64	32.93	81.76	32.19	190.50	624.99	179.21	587.97	↓	↓	135.72	445.27	-38.10	-124.99	-26.83	-88.03	309.47	1015.33	302.52	992.51	1.111	.450	.026	.032	↓	.271	15.50
4	79.83	31.43	78.46	30.89	198.65	651.75	180.56	592.39	↓	↓	139.24	456.84	-27.58	-90.50	-19.42	-63.71	295.38	969.08	290.30	952.43	1.088	.466	.017	.030	↓	.282	16.17
5	75.92	29.89	75.06	29.55	203.30	666.98	180.73	592.96	↓	↓	145.52	477.43	-17.15	-56.25	-12.52	-41.06	280.90	921.60	277.71	911.12	1.059	.487	.022	.027	↓	.313	17.93
6	71.83	28.28	71.45	28.13	205.40	673.87	181.03	593.94	↓	↓	153.16	502.49	-6.96	-22.82	-5.90	-19.37	265.77	871.96	264.36	867.33	1.026	.505	.028	.025	↓	.362	20.73
7	67.49	26.57	67.67	26.64	205.54	674.35	181.75	596.29	↓	↓	162.73	533.90	3.14	10.31	0.76	2.48	249.70	819.23	250.36	821.39	.987	.520	.039	.022	↓	.433	24.80
8	62.81	24.73	63.60	25.04	204.04	669.42	182.83	599.82	↓	↓	174.98	574.09	13.41	43.98	7.82	25.65	232.41	762.5	235.32	772.06	.945	.529	.061	.015	↓	.531	30.42
9	57.71	22.72	59.21	23.31	201.13	659.86	184.06	603.86	↓	↓	191.05	626.82	24.17	79.30	15.71	51.55	213.52	700.53	219.07	718.72	.897	.525	.090	.007	↓	.662	37.91
10	52.02	20.48	54.33	21.39	197.35	647.48	184.72	606.03	↓	↓	212.91	698.54	36.01	118.13	25.05	82.18	192.47	631.46	201.02	659.52	.846	.498	.131	.002	↓	.829	47.49
11	45.52	17.92	48.62	19.14	193.66	635.36	183.42	601.78	↓	↓	245.02	803.88	50.24	164.83	36.80	120.73	168.41	552.53	179.88	590.14	.793	.425	.183	.000	↓	1.037	59.41

(b) Stator

Radial station	LE cm	LE in.	TE cm	TE in.	V_z inlet m/sec	V_z inlet ft/sec	V_z outlet m/sec	V_z outlet ft/sec	V_T inlet m/sec	V_T inlet ft/sec	V_T outlet m/sec	V_T outlet ft/sec	V_R inlet m/sec	V_R inlet ft/sec	V_R outlet m/sec	V_R outlet ft/sec	U inlet m/sec	U inlet ft/sec	U outlet m/sec	U outlet ft/sec	M_{IN}	D	Profile	Shock	Total pressure ratio	Radians	deg
1	86.28	33.97	86.26	33.96	199.92	655.92	187.12	613.92	153.37	503.19	0	0	-0.02	-0.05	0.00	0.01	------	-------	------	-------	0.720	0.475	0.165	0.0	1.466	0.654	37.49
2	83.41	32.84	83.39	32.83	208.92	685.43	192.95	633.05	142.16	466.42	↓	↓	.05	.15	.03	.10	------	-------	------	-------	.728	.430	.111	↓	1.490	.597	34.23
3	80.57	31.72	80.54	31.71	214.28	703.02	196.34	644.17	137.73	451.88	↓	↓	.13	.43	.01	.02	------	-------	------	-------	.738	.409	.077	↓	1.505	.571	32.73
4	77.65	30.57	77.62	30.56	216.96	711.80	197.98	649.53	140.70	461.61	↓	↓	.50	1.65	.21	.70	------	-------	------	-------	.751	.409	.062	↓	1.511	.575	32.96
5	74.63	29.38	74.65	29.39	218.53	716.19	198.99	652.87	146.32	480.06	↓	↓	1.47	4.83	.98	3.23	------	-------	------	-------	.765	.415	.047	↓	1.517	.590	33.83
6	71.48	28.14	71.55	28.17	219.08	718.75	199.33	653.97	153.12	502.37	↓	↓	3.28	10.75	2.54	8.32	------	-------	------	-------	.779	.424	.039	↓	1.521	.610	34.95
7	68.15	26.83	68.30	26.89	219.09	718.80	198.84	652.36	161.59	530.16	↓	↓	5.96	19.54	4.87	15.99	------	-------	------	-------	.795	.437	.042	↓	1.519	.635	36.40
8	64.57	25.42	64.87	25.54	217.61	713.93	198.30	650.59	172.36	565.49	↓	↓	9.84	32.27	8.39	27.51	------	-------	------	-------	.813	.451	.044	.001	1.516	.669	38.35
9	60.68	23.89	61.26	24.12	212.98	698.76	198.14	650.06	186.40	611.54	↓	↓	15.80	51.83	14.49	47.55	------	-------	------	-------	.831	.463	.045	.004	1.513	.717	41.09
10	56.31	22.17	57.38	22.59	199.48	654.45	193.21	633.88	205.41	673.92	↓	↓	24.61	80.75	25.78	84.59	------	-------	------	-------	.845	.485	.045	.011	1.509	.793	45.46
11	50.98	20.07	52.25	20.57	185.65	609.09	157.96	518.23	230.72	756.96	↓	↓	31.65	103.85	35.98	118.05	------	-------	------	-------	.878	.620	.438	.028	1.265	.884	50.63

TABLE IX. - BLADE DESIGN CHARACTERISTICS FOR QF-1 AND QF-2

(a) Rotor

Radial station	Aerodynamic chord, C		Maximum blade thickness, τ_{max}		Thickness of rounded blade edge				Blade solidity, σ	Camber line curvature, φ				Camber angle with axis, θ				Blade setting angle, γ		Maximum thickness location, YL	Camber transition location, XL
					Leading edge, τ_{LE}		Trailing edge, τ_{TE}			Forward, φ_1		Rear, φ_2		Leading edge, θ_{LE}		Trailing edge, θ_{TE}					
	cm	in.	cm	in.	cm	in.	cm	in.		rad	deg	rad	deg	rad	deg	rad	deg	rad	deg		
1	14.290	5.626	0.528	0.208	0.132	0.052	0.116	0.046	1.343	0.072	4.14	0.321	18.42	1.050	60.16	0.657	37.64	0.942	53.99	0.500	0.636
2	14.196	5.589	.538	.212	.135	.053	.116	.046	1.389	.082	4.70	.251	14.41	.993	56.90	.660	37.82	.884	50.64	.500	.590
3	14.115	5.557	.564	.222	.140	.055	.116	.046	1.440	.084	4.79	.223	12.75	.947	54.26	.641	36.73	.836	47.89	.500	.550
4	14.056	5.534	.594	.234	.147	.058	.122	.048	1.498	.092	5.25	.221	12.65	.906	51.91	.593	33.98	.783	44.86	.490	.509
5	14.016	5.518	.632	.249	.157	.062	.126	.050	1.566	.098	5.64	.242	13.85	.867	49.68	.527	30.20	.727	41.68	.480	.468
6	13.993	5.509	.681	.268	.170	.067	.133	.052	1.647	.108	6.18	.276	15.82	.827	47.38	.443	25.38	.663	38.00	.470	.426
7	13.988	5.507	.747	.294	.185	.073	.142	.056	1.746	.116	6.63	.332	19.00	.783	44.86	.336	19.25	.587	33.62	.460	.380
8	14.011	5.516	.831	.327	.208	.082	.153	.060	1.870	.120	6.86	.414	23.72	.731	41.88	.197	11.29	.492	28.21	.450	.331
9	14.072	5.540	.942	.371	.236	.093	.167	.067	2.030	.121	6.95	.529	30.29	.668	38.27	.018	1.03	.374	21.41		.277
10	14.183	5.584	1.094	.431	.274	.108	.192	.075	2.250	.105	5.99	.685	39.23	.583	33.40	-.206	-11.80	.224	12.83		.217
11	14.338	5.645	1.328	.523	.333	.131	.226	.089	2.569	.039	2.21	.887	50.82	.444	25.44	-.482	-27.62	.035	1.98		.151

(b) Stator

Radial station	Aerodynamic chord, C (cm)	(in.)	τ_{max} (cm)	(in.)	τ_{LE} (cm)	(in.)	τ_{TE} (cm)	(in.)	Blade solidity, σ	φ_1 (rad)	(deg)	φ_2 (rad)	(deg)	θ_{LE} (rad)	(deg)	θ_{TE} (rad)	(deg)	γ (rad)	(deg)	YL	XL
1	6.784	2.671	0.678	0.267	0.135	0.053	0.102	0.040	1.402	0.163	9.35	0.343	19.68	0.415	23.78	-0.092	-5.27	0.139	7.98	0.450	0.232
2			.655	.258	.132	.052			1.450	.096	5.52	.332	19.04	.349	20.00	-.080	-4.58	.130	7.46		.204
3			.632	.249	.127	.050			1.502	.067	3.84	.330	18.89	.322	18.45	-.074	-4.24	.128	7.36		.190
4			.610	.240	.122	.048			1.558	.072	4.14	.342	19.59	.338	19.37	-.076	-4.35	.135	7.72		.191
5			.587	.231	.117	.046			1.621	.088	5.06	.360	20.65	.368	21.09	-.081	-4.64	.144	8.26		.196
6	6.787	2.672	.561	.221	.112	.044			1.692	.106	6.08	.382	21.86	.403	23.09	-.085	-4.87	.155	8.89		.202
7	6.787	2.672	.536	.211	.109	.043			1.773	.127	7.30	.407	23.30	.443	25.38	-.091	-5.21	.168	9.65		.207
8	6.792	2.674	.508	.200	.107	.042			1.871	.153	8.79	.437	25.06	.493	28.25	-.098	-5.62	.185	10.60		.214
9	6.810	2.681	.480	.189	.104	.041			1.991	.187	10.73	.478	27.36	.558	31.97	-.106	-6.07	.207	11.86		.221
10	6.871	2.705	.450	.177	.102	.040			2.154	.237	13.56	.536	30.71	.654	37.47	-.119	-6.82	.240	13.73		.230
11	6.909	2.720	.406	.160	.102	.040			2.386	.286	16.38	.611	35.03	.764	43.77	-.133	-7.62	.280	16.07		.233

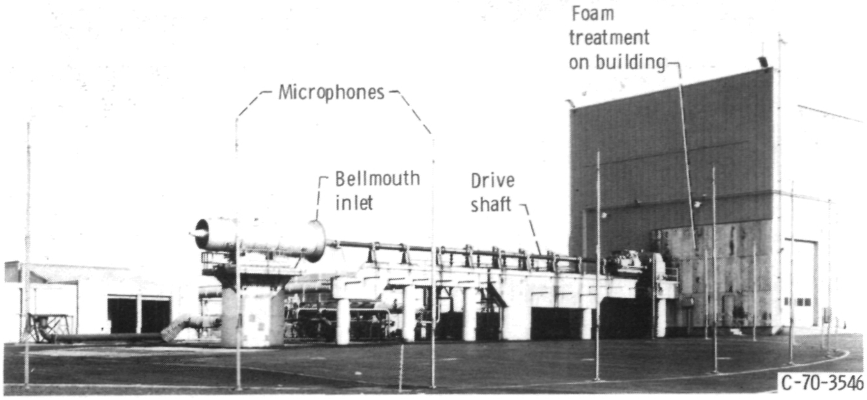


Figure 1. - Test site with fan QF-2 in place.

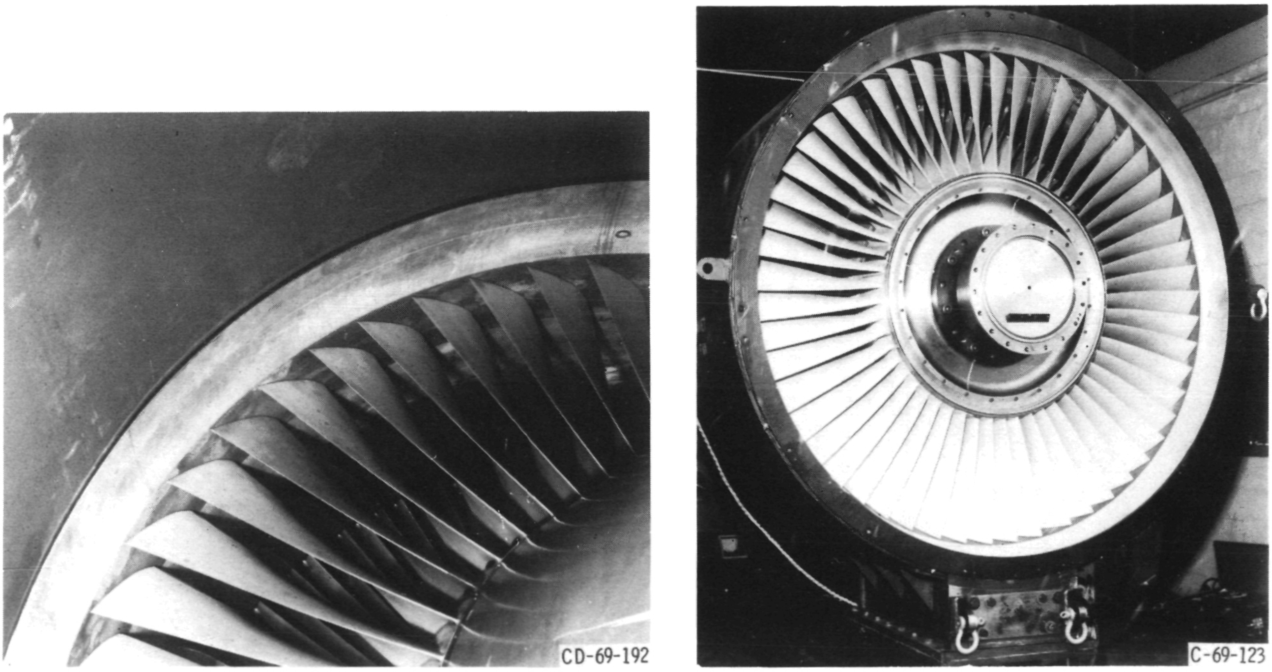


Figure 2. - Fan OF-2 rotor.

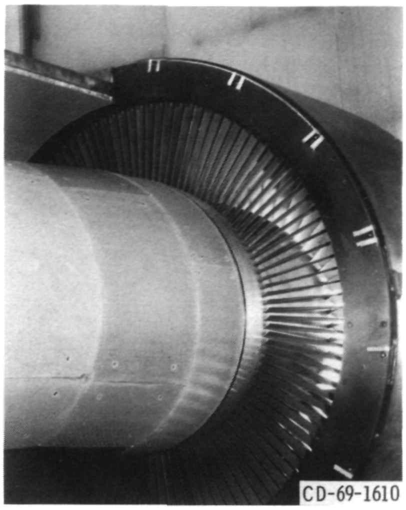


Figure 3. - Fan QF-2 stator.

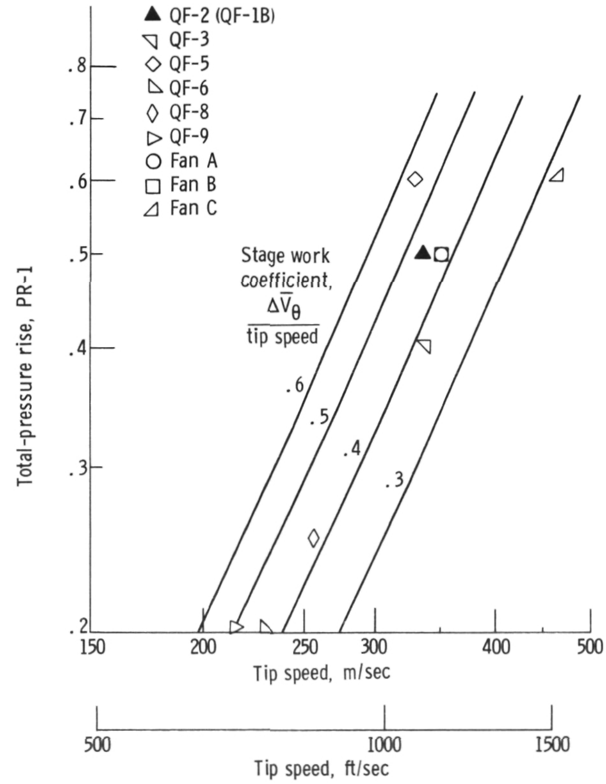


Figure 4. - Matrix of fan parameters - design valves.

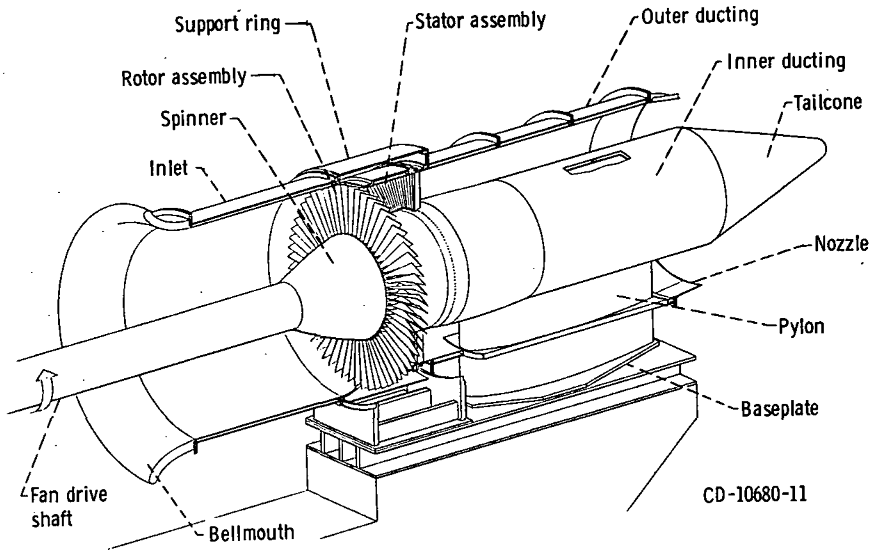
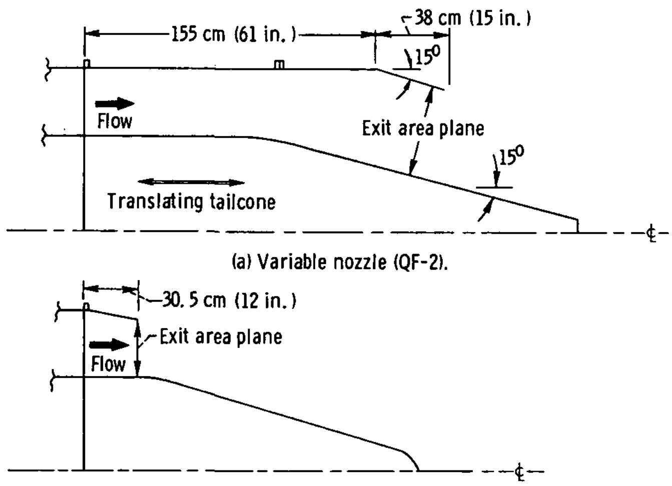


Figure 5. - Quiet fan nacelle assembly.



(a) Variable nozzle (QF-2).

(b) Fixed nozzle (QF-1 and QF-1B).

Figure 6. - Comparison of exhaust nozzles used on fans QF-2 and QF-1B.

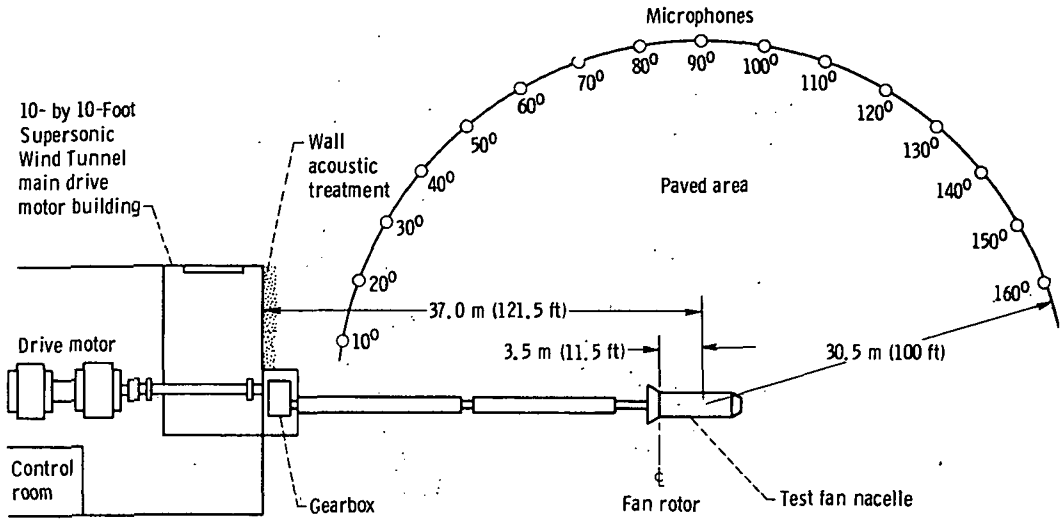


Figure 7. - Plan view of test site. (All dimensions given in m (ft).)

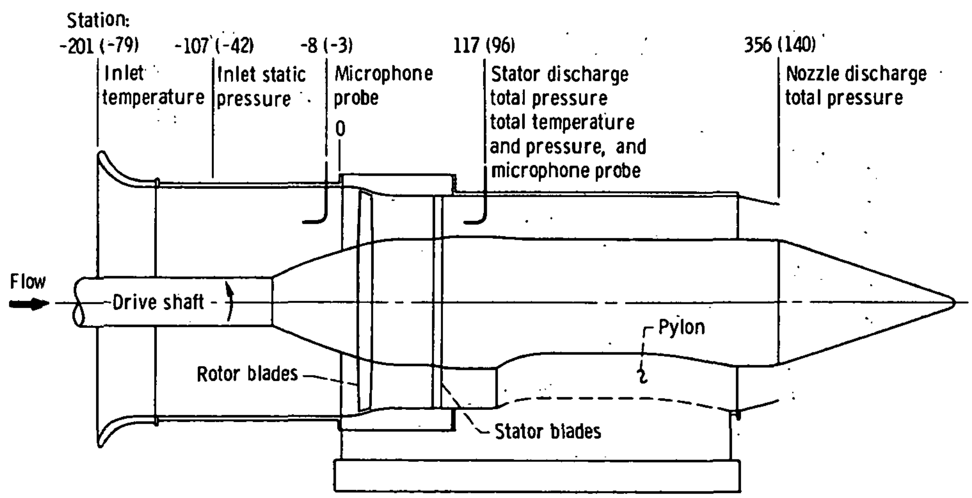


Figure 8. - Fan QF-2 cross section showing axial locations of measurements. (Station numbers are in cm (in.).)

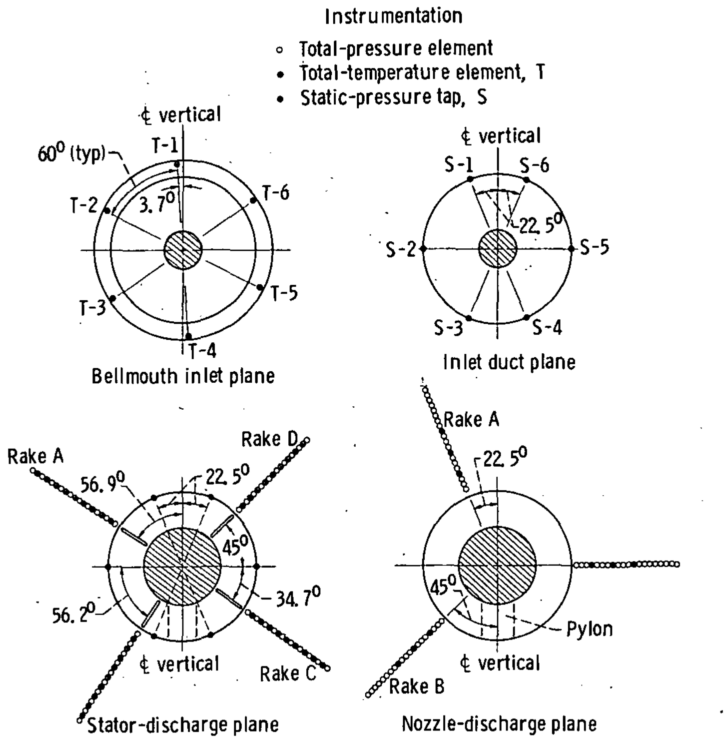


Figure 9. - Detail of fan aerodynamic instrumentation. (All views looking downstream.)

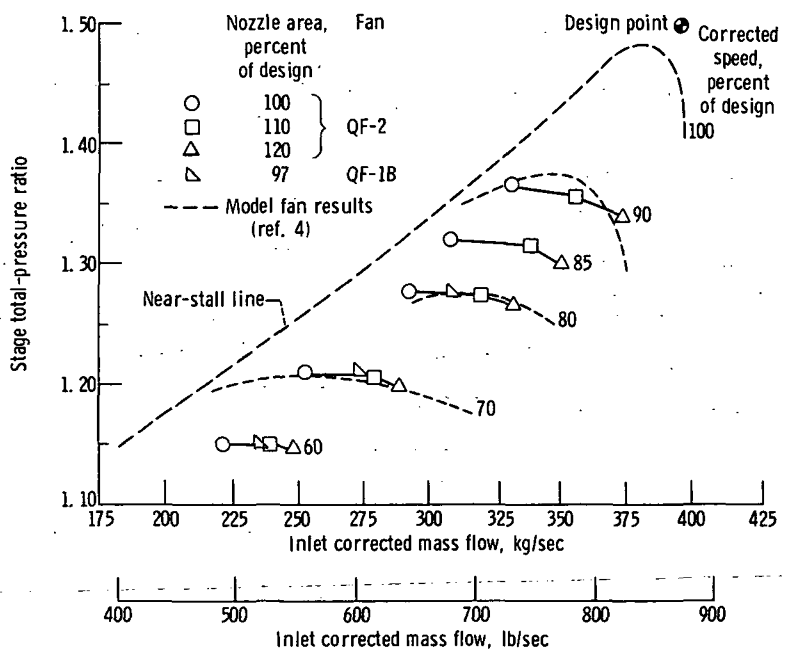
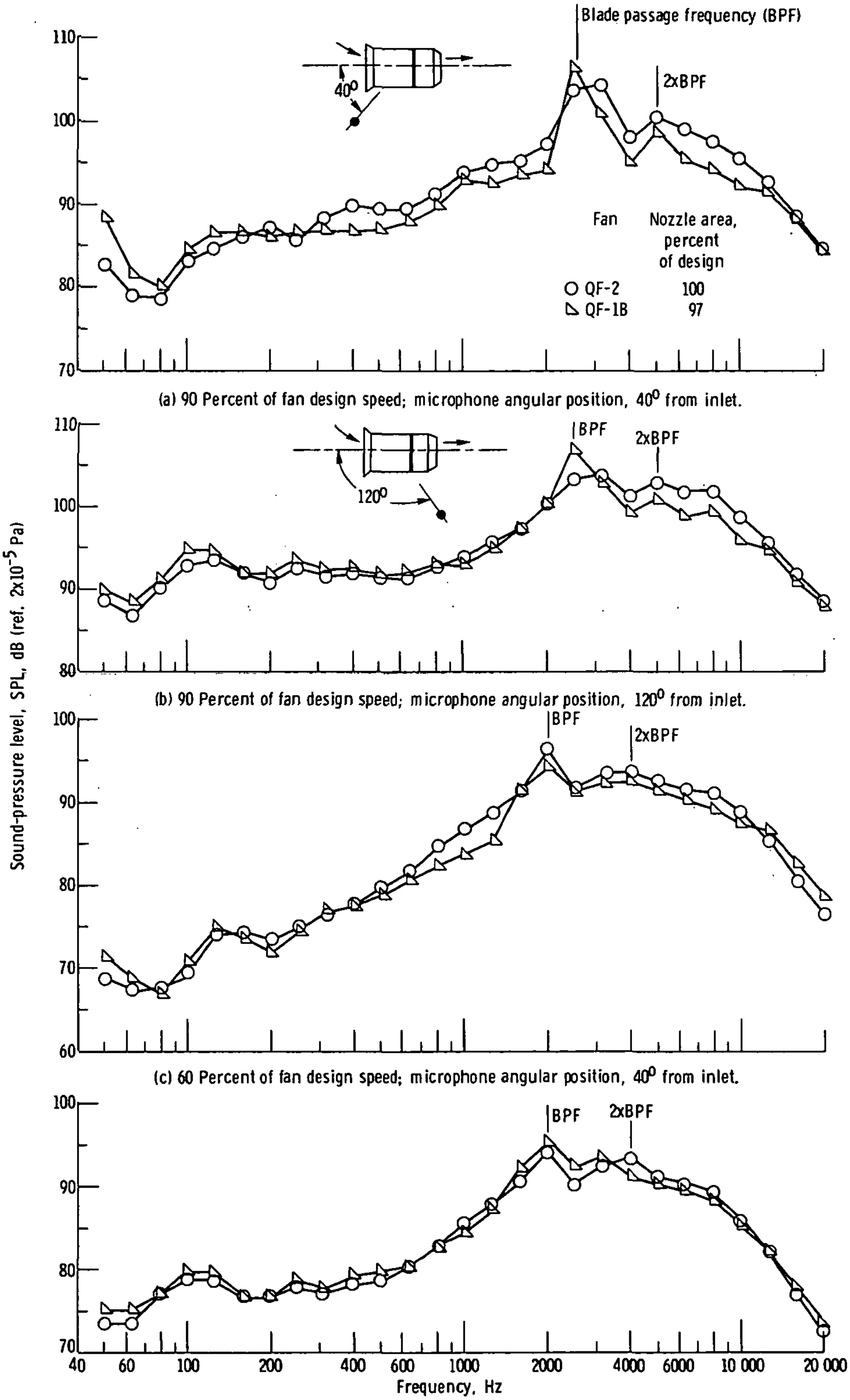


Figure 10. - Fan operating map.



(a) 90 Percent of fan design speed; microphone angular position, 40° from inlet.

(b) 90 Percent of fan design speed; microphone angular position, 120° from inlet.

(c) 60 Percent of fan design speed; microphone angular position, 40° from inlet.

(d) 60 Percent of fan design speed; microphone angular position, 120° from inlet.

Figure 11. - One-third-octave sound pressure spectra.

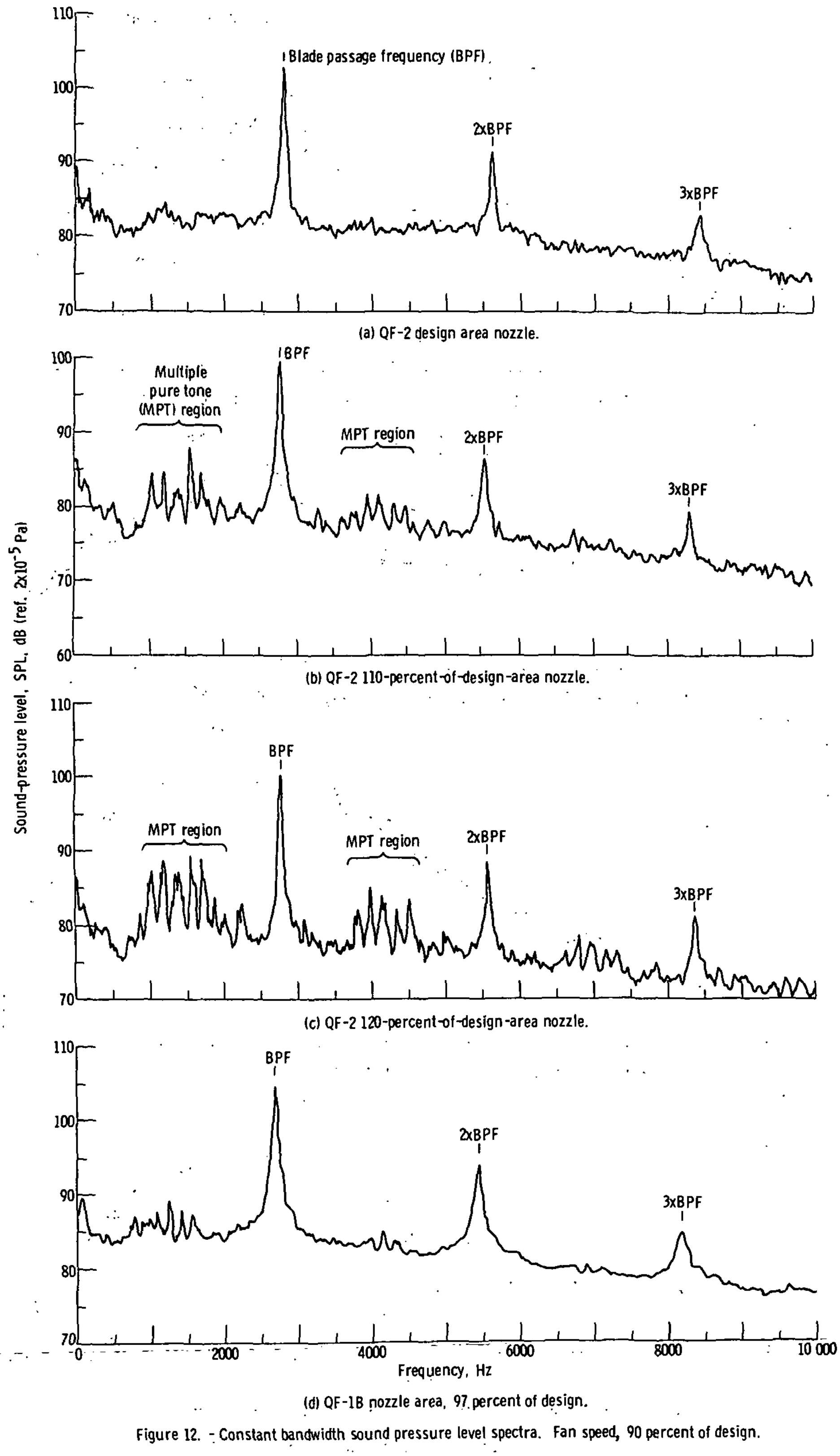


Figure 12. - Constant bandwidth sound pressure level spectra. Fan speed, 90 percent of design.

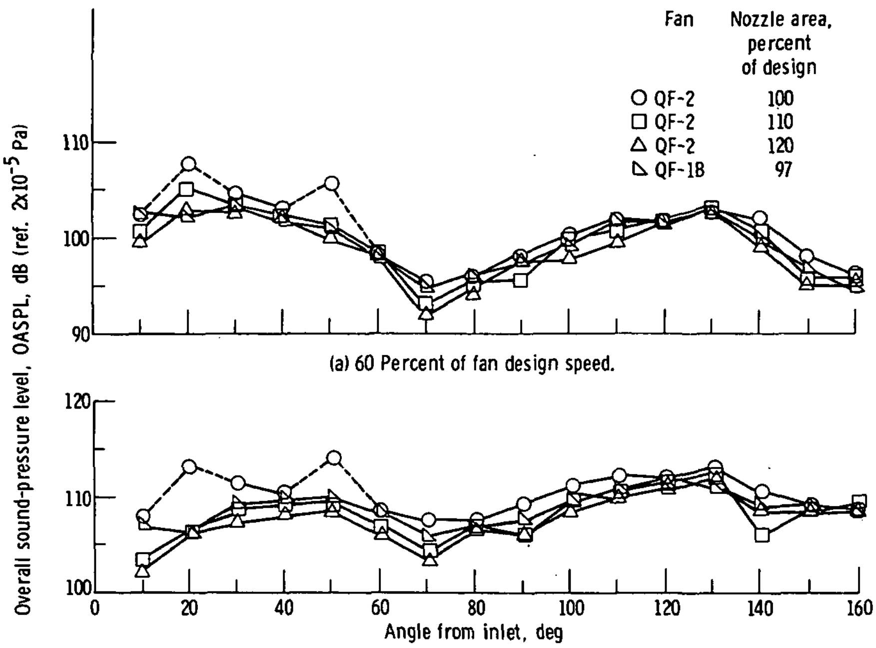
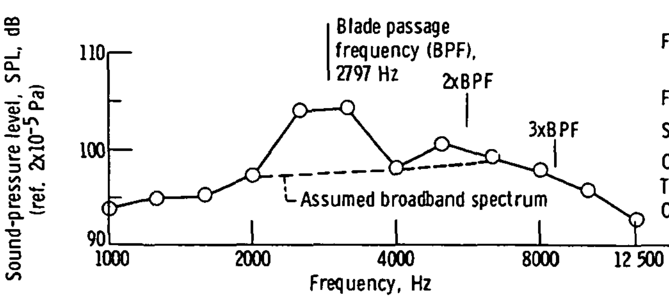


Figure 13. - Overall sound pressure level as function of microphone angular position.



	Data SPL	Broadband	Tone
Fundamental passage tone	103.9	97.4	102.8
	104.3	97.6	103.3
First overtone	100.5	98.4	96.3
Second overtone	Not present		

Overall tone contribution, 106.5 dB

Total OASPL, 110.4 dB

$OASPL_{broadband} = OASPL_{tot} - OASPL_{tone} = 108.1$

Figure 14. - Separated pure tone and broadband sound pressure and power levels in one-third-octave spectrum. Fan QF-2; microphone angular position, 40° from inlet; design area nozzle; 90 percent of fan design speed.

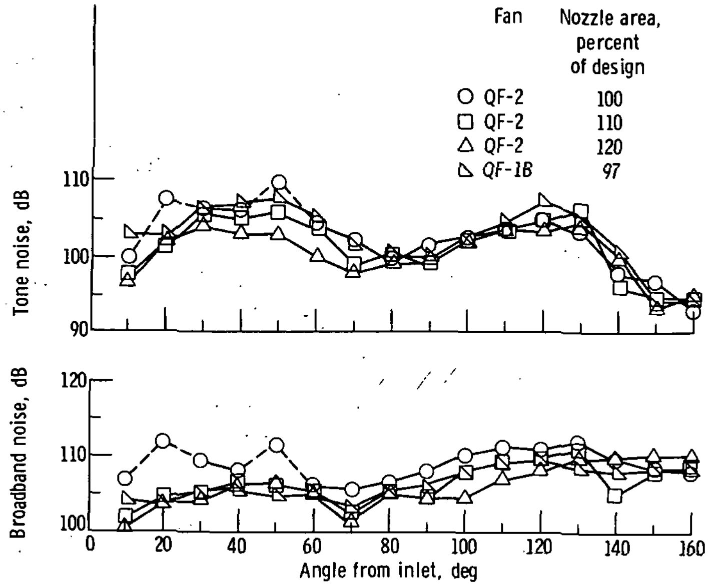


Figure 15. - Tone and broadband sound pressure level directivity. Fan speed, 90 percent of design.

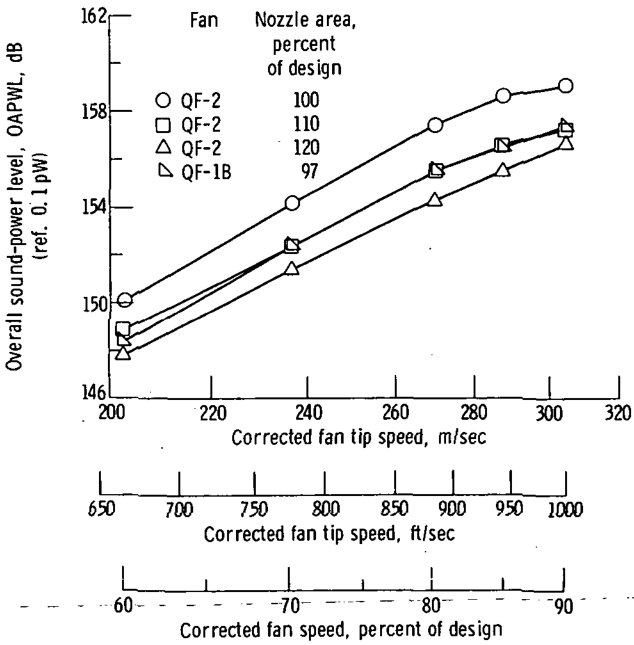


Figure 16. - Overall sound-power level as function of corrected fan speed.

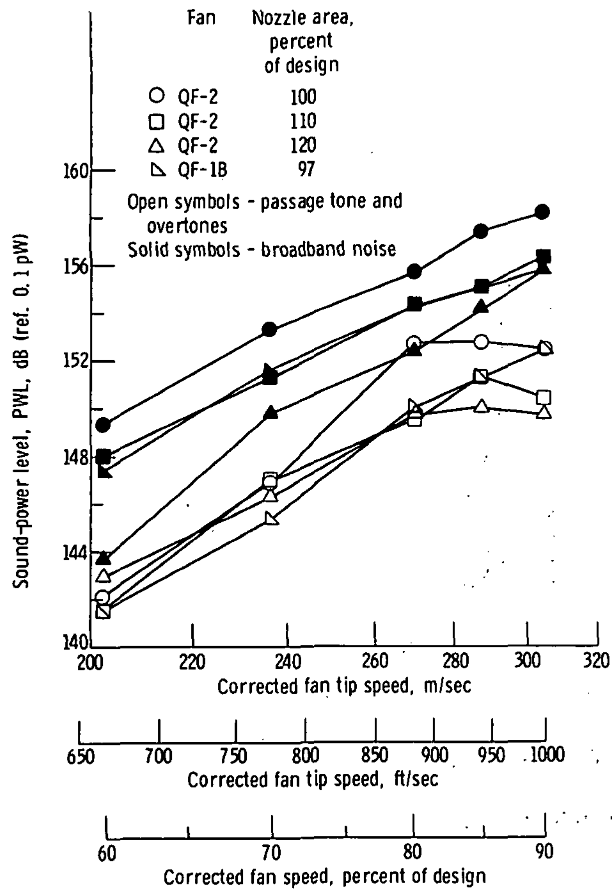


Figure 17. - Effect of fan speed on sound-power noise components.

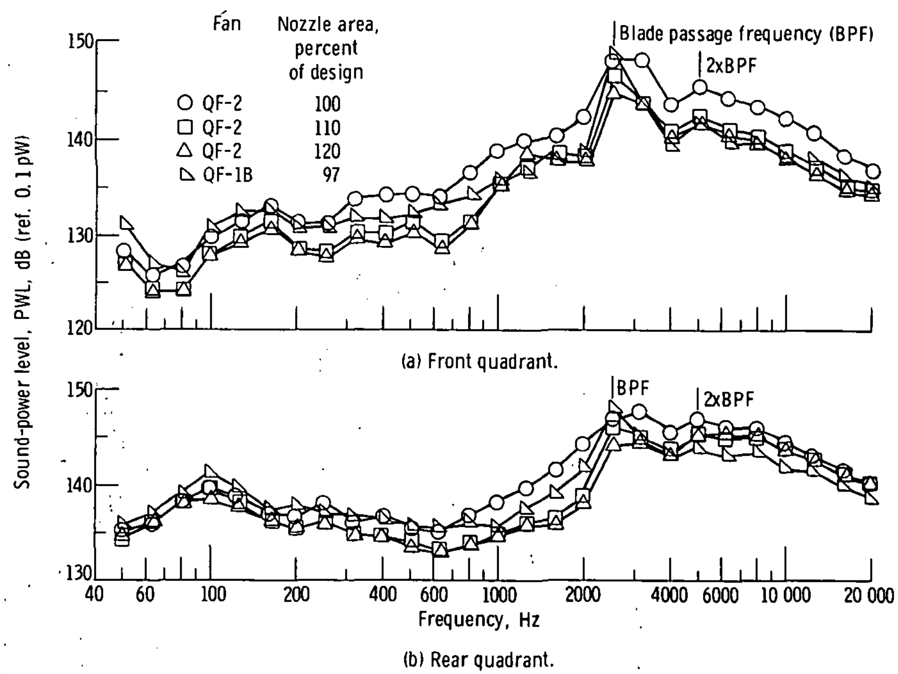


Figure 18. - Comparison of QF-2 and QF-1B sound-power-level spectra. Fan speed, 90 percent of design.

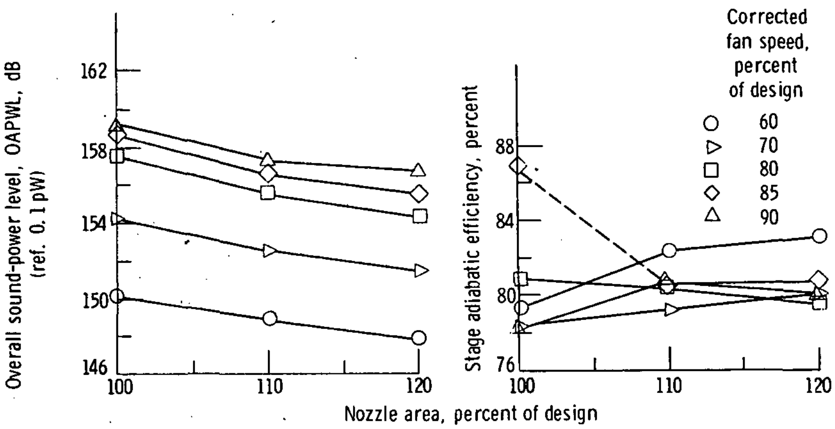


Figure 19. - Overall power level and efficiency as functions of nozzle area.

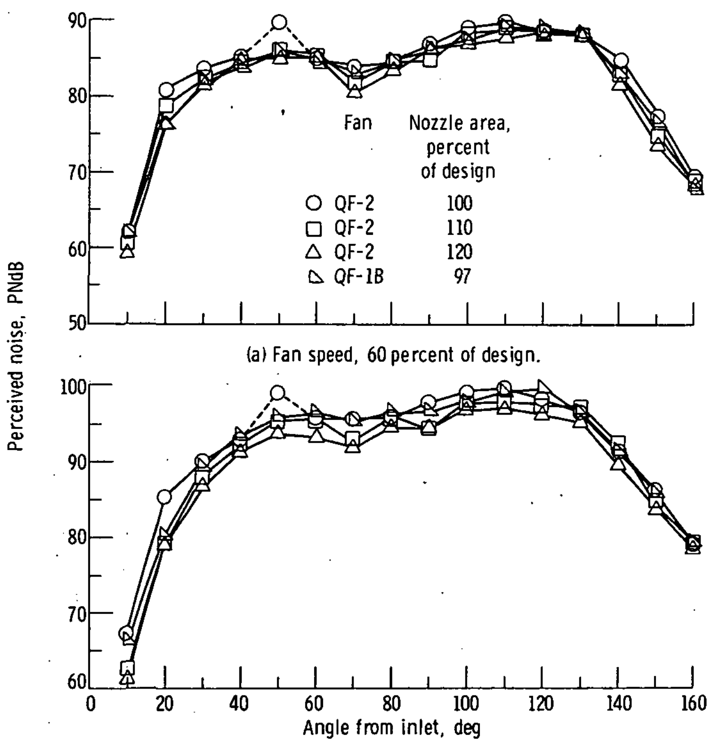


Figure 20. - Perceived-noise level on 304.8-meter (1000-ft) sideline.

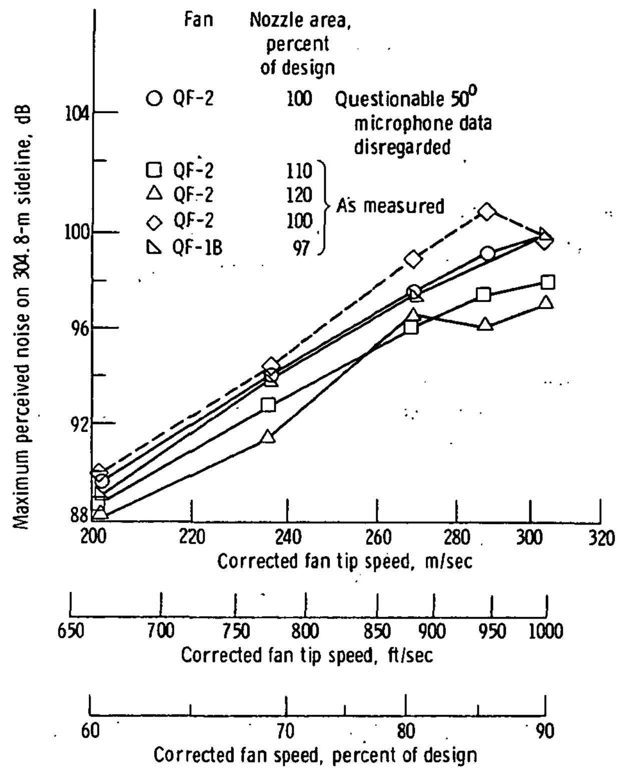


Figure 21. - Maximum perceived noise on 304.8-meter (1000-ft) sideline as function of fan speed.

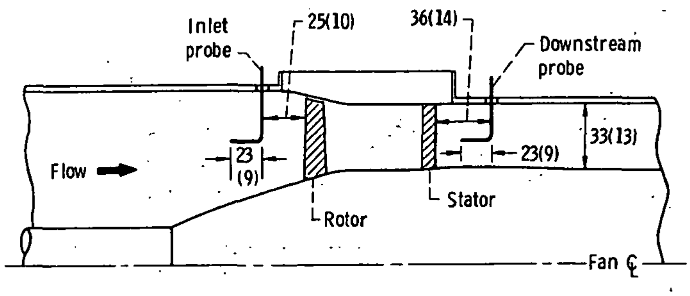
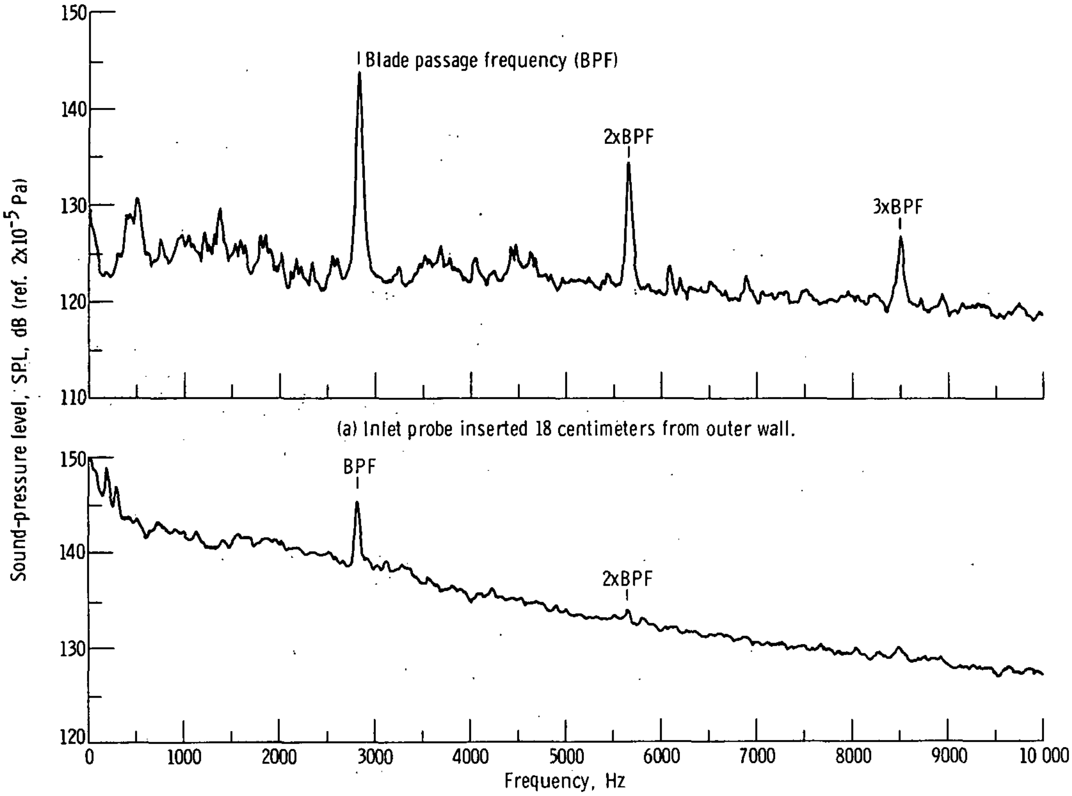


Figure 22. - Acoustic probe installation. (Dimensions are in cm (in.).)



(b) Exhaust probe inserted 19 centimeters from outer wall.

Figure 23. - Typical in-duct narrow-band spectra. Fan speed, 90 percent of design; design nozzle area.

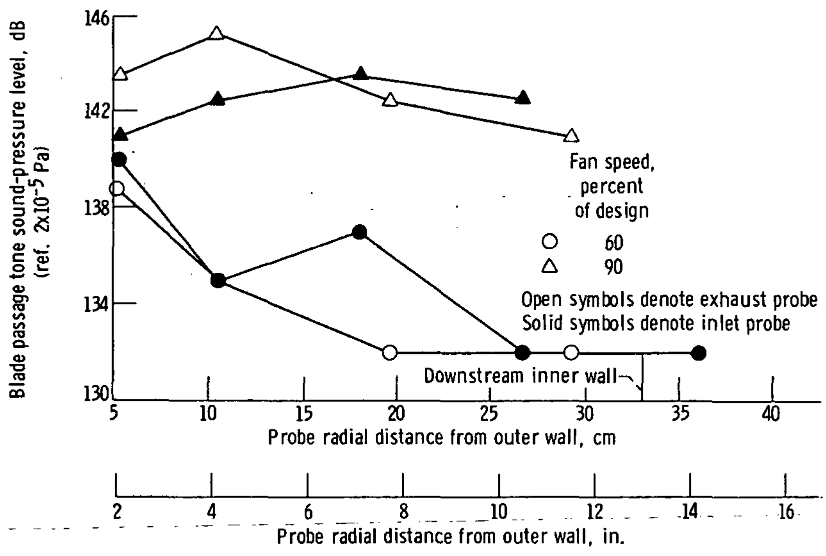


Figure 24. - Acoustic probe result: passage tone sound-pressure level from narrow-band spectra (upstream inner wall at 56 centimeters (22 in.))

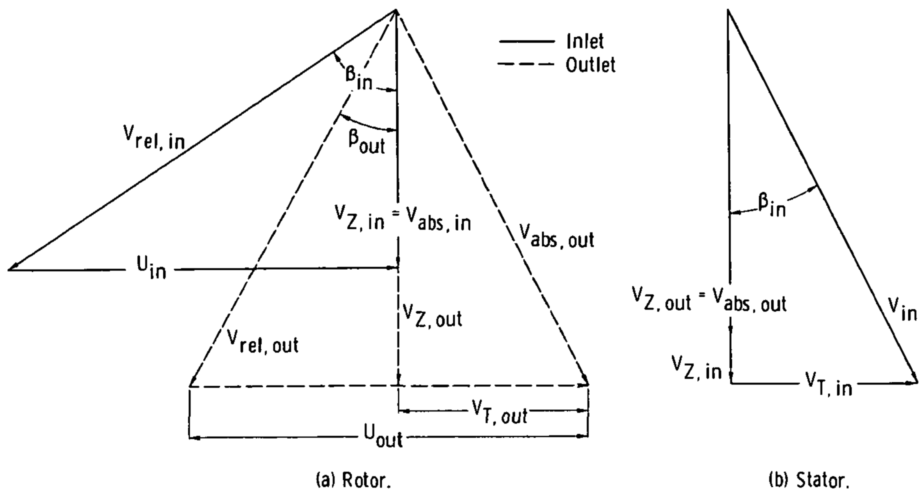


Figure 25. - Blade velocity diagrams. (Components are shown in axial-tangential plane. Radial component is perpendicular to this plane. Positive radial velocities are radially outward.)

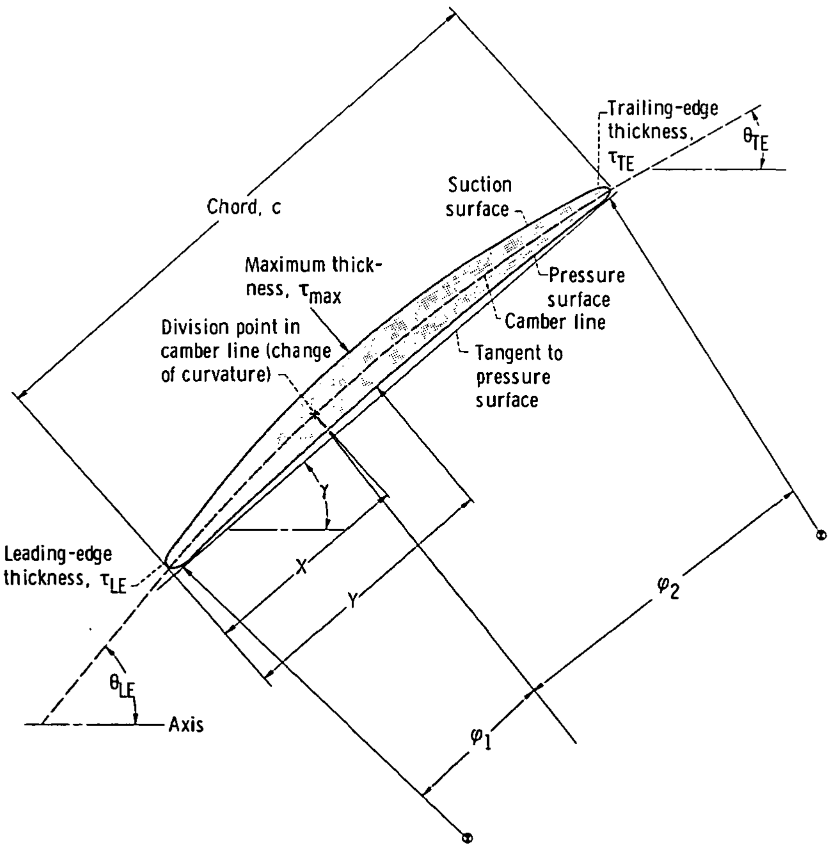


Figure 26. - Blade geometry notation.

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